TITLE OF THE INVENTION

VIDEO ENCODING METHOD AND APPARATUS AND VIDEO DECODING METHOD AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a Continuation Application of PCT Application No. PCT/JP03/00425, filed January 20, 2003, which was not published under PCT Article 21(2) in English.

This application is based upon and claims the benefit of priority from the prior Japanese Patent Applications No. 2002-010874, filed January 18, 2002; No. 2002-108102, filed April 10, 2002; No. 2002-341238, filed November 25, 2002; and No. 2002-341239, filed November 25, 2002, the entire contents of all of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a motion compensation predictive inter-frame encoding method and apparatus and motion compensation predictive inter-frame decoding method and apparatus, which use a plurality of reference frames.

2. Description of the Related Art

As motion compensation predictive inter-frame encoding methods, MPEG-1 (ISO/IEC11172-2), MPEG-2 (ISO/IEC13818-2), MPEG-4 (ISO/IEC14496-2), and the like have been widely used. In these encoding schemes,

encoding is performed by a combination of intra-frame encoded pictures (I pictures), forward predictive inter-frame encoded pictures (P pictures), and bi-directional predictive encoded pictures (B pictures).

A P picture is encoded by using the immediately preceding P or I picture as a reference picture. A B picture is encoded by using the immediately preceding and succeeding P or I pictures as reference pictures. In MPEG, a predictive picture can be selectively generated for each macroblock from one or a plurality of picture frames. In the case of P pictures, a predictive picture is generally generated on a macroblock basis from one reference frame. In the case of B pictures, a predictive picture is generated by either a method of generating a predictive picture from one of a forward reference picture and a backward reference picture, or method of generating a predictive picture from the average value of reference macroblocks extracted from both a forward reference picture and a backward reference picture. The information of these prediction modes is embedded in encoded data for each macroblock.

In either of these predictive encoding methods, however, when the same picture moves temporally and horizontally between frames in an area equal to or larger than the size of each macroblock, a good

prediction result can be obtained. With regard to temporal enlargement/reduction and rotation of pictures or time jitters in signal amplitude such as fade-in and fade-out, however, high prediction efficiency cannot

5   always be obtained by the above predictive encoding method. In encoding at a constant bit rate, in particular, if pictures with poor prediction efficiency are input to the encoding apparatus, a great deterioration in picture quality may occur. In encoding at a

10   variable bit rate, a large code amount is assigned to pictures with poor prediction efficiency to suppress a deterioration in picture quality, resulting in an increase in the total number of encoded bits.

On the other hand, temporal enlargement/reduction,

15   rotation, and fade-in/fade-out of pictures can be approximated by affine transformation of video signals. Predictions using affine transformation will therefore greatly improve the prediction efficiency for these pictures. In order to estimate a parameter for affine

20   transformation, an enormous amount of parameter estimation computation is required at the time of encoding.

More specifically, a reference picture must be transformed by using a plurality of transformation

25   parameters, and one of the parameters which exhibits the minimum prediction residual error must be determined. This requires an enormous amount of

transformation computation. This leads to an enormous amount of encoding computation or an enormous increase in hardware cost and the like. In addition, a transformation parameter itself must be encoded as well as a prediction residual error, and hence the encoded data becomes enormous. In addition, inverse affine transformation is required at the time of decoding, resulting in a great amount of decoding computation or a very high hardware cost.

As described above, in the conventional video encoding methods such as MPEGs, sufficient prediction efficiency cannot be obtained with respect to temporal changes in video pictures other than translations. In addition, in the video encoding and decoding method using affine transformation, although prediction efficiency itself can be improved, the overhead for encoded data increases and the encoding and decoding costs greatly increase.

BRIEF SUMMARY OF THE INVENTION

It is an object of the present invention to provide a video encoding method and apparatus and video decoding method and apparatus which can suppress increases in computation amount and the overhead for encoded data while greatly improving prediction efficiency with respect to fading pictures, in particular, in which the conventional video encoding methods such as MPEGs have a weak point.

According to a first aspect of the present
invention, there is provided a video encoding method of
performing motion compensation predictive inter-frame
encoding of a to-be-encoded frame by referring to a
5   plurality of reference frames for each macroblock,
comprising generating a plurality of macroblocks from
the plurality of reference frames, selecting, as a
predictive macroblock, one of macroblocks obtained by a
linear interpolation prediction or a linear extrapola-
10   tion prediction using one of the plurality of reference
macroblocks, an average value of the plurality of
reference macroblocks, or the plurality of reference
macroblocks, and encoding a predictive error signal
between the selected predictive macroblock and a
15   to-be-encoded macroblock, prediction mode information,
and a motion vector.

According to a second aspect of the present
invention, there is provided a video decoding method of
decoding motion compensation predictive inter-frame
20   encoded data by referring to a plurality of reference
frames for each macroblock, comprising receiving
encoded motion vector data, encoded prediction mode
information, and encoded predictive error signal,
selecting, in accordance with the motion vector data
25   and the prediction mode information, whether to (a)
generate a predictive macroblock from a specific
reference frame of the plurality of reference frames,

(b) generate a plurality of macroblocks from the plurality of reference frames so as to generate an average value of the plurality of reference frames as a predictive macroblock, or (c) generate a predictive macroblock by a linear extrapolation prediction or linear interpolation prediction, and generating a decoded frame by adding the generated predictive macroblock and the predictive error signal.

In conventional video encoding schemes such as MPEGs, in order to generate a predictive macroblock from a plurality of reference frames, reference macroblocks are extracted from the respective reference frames, and the average value of signals of the extracted macroblocks is used. According to such a conventional video encoding scheme, however, when the amplitude of a picture signal varies over time due to fading or the like, the prediction efficiency deteriorates. In contrast, according to the video encoding scheme of the first or second aspect of the present invention, since a predictive picture is generated by extrapolation or interpolation based on a linear prediction from a plurality of frames, when the amplitude of a picture signal monotonously varies over time, the prediction efficiency can be greatly improved. This can realize high-picture-quality, high-efficiency encoding.

In inter-frame encoding, in general, encoded

pictures are used as reference frames on the encoding
side, and decoded pictures are used as reference frames
on the decoding side. For this reason, the influence
of encoding noise in reference frames becomes a factor
that degrades the prediction efficiency. Averaging the
reference macroblocks extracted from a plurality of
reference frames exhibits a noise removing effect and
hence contributes to an improvement in encoding
efficiency. This effect is equivalent to a technique
known as a loop filter in predictive encoding.

According to the first and second aspects of the
present invention, averaging processing of a plurality
of reference frames, which has a high loop filter
effect, linear interpolation which is effective for
fading pictures and the like, or an optimal prediction
mode for linear interpolation can be selected in
accordance with an input picture. This makes it
possible to improve encoding efficiency for arbitrary
input pictures.

According to a third aspect of the present
invention, there is provided a video encoding method in
which in motion compensation predictive inter-frame
encoding performed by referring to a plurality of video
frames for each macroblock, a plurality of reference
frames are two frames encoded immediately before a
to-be-encoded frame, and in a linear extrapolation
prediction based on the plurality of reference

macroblocks, the predictive macroblock is generated by subtracting, from a signal obtained by doubling the amplitude of the reference macroblock signal generated from the immediately preceding reference frame, the reference macroblock signal generated from a reference frame preceding one frame from the immediately preceding reference frame.

According to a fourth aspect of the present invention, there is provided a video decoding method in which in motion compensation predictive inter-frame decoding performed by referring to a plurality of video frames for each macroblock, the plurality of reference frames are two frames decoded immediately before a to-be-encoded frame, and in a linear extrapolation prediction based on the plurality of reference macroblocks, the predictive macroblock is generated by subtracting, from the signal obtained by doubling the amplitude of the reference macroblock signal generated from the immediately preceding reference frame, the reference macroblock signal generated from a reference frame preceding one frame from the immediately preceding reference frame.

As described above, in conventional video encoding schemes such as MPEGs, when the amplitude of a picture signal changes over time due to fading or the like, the prediction efficiency deteriorates. For example, letting $V(t)$ be a picture frame at time $\underline{t}$, and $V'(t)$ be

a picture frame at time $\underline{t}$ which has undergone fading processing, fade-in and fade-out can be realized by equations (1) and (2). In equation (1), (a) indicates a fade period; fade-in starts at time t = 0 and ends at time T. In equation (2), (b) indicates a fade period; fade-out starts at time T0 and ends at time T0 + T.

$$
Y'(t) = \begin{cases} Y(t) \times t/T & (0 \leqq t < T) \quad \text{(a)} \\ Y(t) & (t \geqq T) \quad \text{(b)} \end{cases} \tag{1}
$$

$$
Y'(t) = \begin{cases} Y(t) & (t \leqq T0) \quad \text{(a)} \\ Y(t) \times (T-t+T0)/T & (T0 < t < T0+T) \quad \text{(b)} \\ 0 & (t \geqq T0+T) \quad \text{(c)} \end{cases} \tag{2}
$$

Assume that a frame Y'(t) at time $\underline{t}$ when fade processing is performed is a to-be-encoded frame, and two frames Y'(t-1) and Y'(t-2) subjected to the same fade processing at time t-1 and time t-2 are reference frames.

Consider first a case wherein a predictive picture P(t) is generated from the average value of these two frames, as indicated by equation (3).

$$
P(t) = \{Y'(t-1) + Y'(t-2)\}/2 \tag{3}
$$

In consideration of the fade periods (a) and (b) in equations (1) and (2), the predictive picture obtained by equation (3) is represented by equations (4) and (5) as follows:

$$
P(t) = \{Y(t-1) \times (t-1)
$$
$$
/T + Y(t-2) \times (t-2)/T\}/2 \tag{4}
$$

$$P(t)=\{Y(t-1) \times (T-t+1+T0)$$

$$/T+Y(t-2) \times (T-t+2+T0)/T\}/2 \tag{5}$$

If there is no time jitter in an original signal $Y(t)$ before fading, i.e., $Y(t) = C$ (constant) assuming that $Y(t)$ is constant regardless of $\underline{t}$, equations (4) and (5) are modified into equations (6) and (7):

$$P(t)=C \times (2t-3)/2T \tag{6}$$

$$P(t)=C \times (2T-2t+3+2T0)/2T \tag{7}$$

On the other hand, the to-be-encoded signal $Y'(t)$ is expressed by equations (8) and (9):

$$Y'(t)=C \times t/T \tag{8}$$

$$Y'(t)=C \times (T-t+T0)/T \tag{9}$$

A predictive error signal $D(t)$ obtained by subtracting the predictive picture $P(t)$ given by equations (6) and (7) from $Y'(t)$ given by equations (8) and (9) is expressed by equations (10) and (11):

$$D(t)=C \times 3/2T \tag{10}$$

$$D(t)=-C \times 3/2T \tag{11}$$

According to the video encoding methods of the third and fourth aspects of the present invention, the predictive picture $P(t)$ expressed by equation (12) is generated.

$$P(t)=2 \times Y'(t-1)-Y'(t-2) \tag{12}$$

Assuming that $Y(t) = C$ (constant) as in the above case, a predictive picture at fade-in expressed by equation (1) and a predictive picture at fade-out expressed by equation (2) are represented by

$$P(t) = C \times t/T \tag{13}$$

$$P(t) = C \times (T-t+T0)/T \tag{14}$$

Equations (13) and (14) coincide with the
to-be-encoded pictures represented by equations (8) and
(9). In either of the cases, the predictive error
signal D(t) obtained by subtracting the predictive
picture from the encoded picture becomes 0. As
described above, with regard to fading pictures,
conventional motion compensation techniques such as
MPEGs cause residual error signals. In contrast, as is
obvious, according to the third and fourth aspects of
the present invention, no residual error signals are
produced, and the prediction efficiency greatly
improves.

In equations (1) and (2), 1/T represents the speed
of change in fade-in and fade-out. As is obvious from
equations (10) and (11), in conventional motion
compensation, a residual error increases as the speed
of change in fade increases, resulting in a deteriora-
tion in encoding efficiency. According to the video
encoding methods of the third and fourth aspects of the
present invention, high prediction efficiency can be
obtained regardless of the speed of change in fade.

According to a fifth aspect of the present
invention, in addition to the video encoding methods of
the first and third aspects of the present invention,
there is provided a video encoding method in which

the to-be-encoded motion vector is a motion vector associated with a specific one of the plurality of reference frames.

In addition to the video encoding methods of the second and fourth aspects of the present invention, according to a sixth aspect of the present invention, there is provided a video encoding method in which the received motion vector data is a motion vector associated with a specific one of the plurality of reference frames, and the motion vector data is scaled/converted in accordance with the inter-frame distances between the to-be-decoded frame and reference frames to generate motion vectors for the remaining reference frames.

By the methods according to the first to fourth aspects of the present invention, a prediction efficiency higher than that in the prior art can be obtained with respect to fading pictures and the like by using a plurality of reference pictures. If, however, motion vectors for a plurality of reference pictures are multiplexed into encoded data for each encoded macroblock, the encoding overhead increases. According to an encoding scheme such as ITU-TH. 263, an encoding method called a direct mode is available, in which no motion vector for a B picture is sent, and a motion vector for the B picture is obtained by scaling a motion vector for a P picture, which strides over the

B picture, in accordance with the inter-frame distance between a reference picture and a to-be-encoded picture. This direct mode encoding method is a model in which a to-be-encoded video picture is approximated to a picture whose moving speed is almost constant or 0 when viewed in a short period of time corresponding to several frames. In many cases, this method can reduce the number of encoded bits of the motion vector.

According to the methods of the fifth and sixth aspects of the present invention, as in the direct mode for B pictures, in the case of P pictures, only one motion vector of the motion vectors for a plurality of reference frames is encoded, and on the decoding side, the received motion vector can be scaled in accordance with the inter-frame distance from a reference picture. This makes it possible to achieve the same improvement in encoding efficiency as that achieved by the methods according to the first to fourth aspects of the present invention without increasing the encoding overhead.

In addition to the method according to the fifth aspect of the present invention, there is provided a method according to a seventh aspect of the present invention, in which the motion vector associated with the specific reference frame is a motion vector normalized in accordance with the inter-frame distance between the reference frame and the frame to be encoded.

In addition to the method according to the sixth
aspect of the present invention, there is provided a
method according to an eighth aspect, in which the
motion vector associated with the received specific
5   reference frame is a motion vector normalized in
accordance with the inter-frame distance between the
reference frame and the frame to be encoded.

According to the methods of the seventh and eighth
aspects of the present invention, a reference scale for
10   a motion vector to be encoded is constant regardless of
whether the inter-frame distance changes, and scaling
processing for motion vectors for the respective
reference frames can be done by computation using only
the information of the inter-frame distance between
15   each reference frame and the frame to be encoded.
Division is required to perform arbitrary scaling
operation. However, normalizing a motion vector to be
encoded with the inter-frame distance makes it possible
to perform scaling processing by multiplication alone.
20   This can reduce the encoding and encoding costs.

In addition to the methods according to the first
and third aspects of the present invention, there is
provided a method according to a ninth aspect of the
present invention, in which the motion vector to be
25   encoded includes the first motion vector associated
with a specific one of the plurality of reference
frames and a plurality of motion vectors for the

remaining reference frames, and the plurality of motion
vectors are encoded as differential vectors between the
plurality of motion vectors and motion vectors obtained
by scaling the first motion vector in accordance with
5 the inter-frame distances between the to-be-encoded
frame and the plurality of reference frames.

In addition to the methods according to the second
and fourth aspects, there is provided a method
according to a 10th aspect of the present invention, in
10 which the received motion vector data includes a motion
vector associated with a specific one of the plurality
of reference frames and differential vectors associated
with the remaining reference frames. The motion vector
data is scaled/converted in accordance with the
15 inter-frame distances between a to-be-decoded frame and
the reference frames. The resultant data are then
added to the differential vectors to generate motion
vectors associated with the plurality of reference
frames except for the specific one frame.

20 According to the methods of the fifth and sixth
aspects of the present invention, in the case of still
pictures or pictures with a constant moving speed, the
prediction efficiency can be improved by using a
plurality of reference frames without increasing the
25 encoding overhead for motion vector information. If,
however, the moving speed is not constant, a sufficient
prediction efficiency may not be obtained by simple

scaling of motion vectors alone.

According to a dual-prime prediction which is one prediction mode in MPEG2 video encoding, in a motion prediction using two consecutive fields, a motion vector for one field and a differential vector between a motion vector obtained by scaling the motion vector in accordance with the inter-field distance and a motion vector for the other field are encoded. A motion vector is expressed with a 1/2 pixel resolution. By averaging the reference macroblocks of the two fields, a loop filter effect is produced by an adaptive spatiotemporal filter. In addition, an increase in encoding overhead can be suppressed. This greatly contributes to an improvement in encoding efficiency.

According to the methods of the ninth and 10th aspects of the present invention, in addition to an effect similar to that obtained by a dual-prime prediction, i.e., the loop filter effect produced by an adaptive spatiotemporal filter, the prediction efficiency for fading pictures and the like can be improved. This makes it possible to obtain an encoding efficiency higher than that in the prior art.

In addition to the methods of the first, third, fifth, seventh, and ninth aspects, there is provided a method according to a 11th aspect of the present invention, in which the prediction mode information includes the first flag indicating a prediction using a

specific reference frame or a prediction using a
plurality of reference frames and the second flag
indicating that the prediction using the plurality of
reference frames is a prediction based on the average

5   value of a plurality of reference macroblocks or a
prediction based on linear extrapolation or linear
interpolation of a plurality of reference macroblock,
and the second flag is contained in the header data of
an encoded frame or the header data of a plurality of

10   encoded frames.

In addition to the methods of the second, fourth,
sixth, eighth, and 10th aspects, there is provided a
method according to a 12th aspect of the present
invention, in which the prediction mode information

15   includes the first flag indicating a prediction using a
specific reference frame or a prediction using a
plurality of reference frames and the second flag
indicating that the prediction using the plurality of
reference frames is a prediction based on the average

20   value of a plurality of reference macroblocks or a
prediction based on linear extrapolation or linear
interpolation of a plurality of reference macroblock,
and the second flag is received as the header data of
an encoded frame or part of the header data of a

25   plurality of encoded frames.

As described above, according to the present
invention, an improvement in prediction efficiency and

high-efficiency, high-picture-quality encoding can be realized by adaptively switching between the operation of generating a predictive macroblock, for each macroblock of an encoded frame, from only a specific

5   reference frame of a plurality of reference frames, the operation of generating a predictive macroblock from the average value of a plurality of reference pictures, and the operation of generating a predictive macroblock by linear extrapolation or linear interpolation of a

10   plurality of reference pictures.

For example, a prediction from only a specific reference frame of a plurality of reference frames (prediction mode 1 in this case) is effective for a picture portion in a single frame at which a background

15   alternately appears and disappears over time. With regard to a picture portion with little time jitter, a prediction from the average value of a plurality of reference pictures (prediction mode 2 in this case) makes it possible to obtain a loop filter effect of

20   removing encoding distortion in reference pictures. When the amplitude of a picture signal such as a fading picture varies over time, the prediction efficiency can be improved by linear extrapolation or linear inter- polation of a plurality of reference pictures

25   (prediction mode 3 in this case).

In general, in a conventional encoding scheme, when optimal prediction modes are to be selectively

switched for each macroblock in this manner, a flag indicating a prediction mode is encoded for each macroblock while being contained in header data of each macroblock. If many prediction modes are selectively used, the encoding overhead for flags indicating the prediction modes increases.

According to the methods of the 11th and 12th aspects of the present invention, a combination of prediction modes to be used is limited to a combination of prediction modes 1 and 2 or a combination of prediction modes 1 and 3 for each encoded frame. The second flag indicating one of the above combinations is prepared, together with the first flag indicating prediction mode 1, prediction mode 2, or prediction mode 3. The second flag indicating the combination of the prediction modes is contained in the header data of an encoded frame. The first flag indicating a prediction mode can be changed for each macroblock and is contained in the header data of the macroblock. This can reduce the overhead associated with the prediction modes in encoded data.

When the amplitude of a picture signal such as a fading picture changes over time, the amplitudes uniformly changes over time within the frame. For this reason, there is no need to switch between prediction mode 2 and prediction mode 3 for each macroblock; no deterioration in prediction efficiency occurs even if a

prediction mode is fixed for each frame.

A background or the like alternately appears and disappears over time within a frame regardless of a change in the amplitude of a picture signal over time. If, therefore, a background is fixed for each frame, the prediction efficiency deteriorates. This makes it necessary to switch optimal prediction modes for each macroblock using the first flag. Separately setting the flags indicating the prediction modes in the headers of a frame and macroblock in the above manner makes it possible to reduce the encoding overhead without degrading the prediction efficiency.

According to a 13th aspect of the present invention, there is provided a video encoding method, in which in motion compensation predictive inter-frame encoding performed by referring to a plurality of video frames for each macroblock, a predictive macroblock is generated by a linear prediction from the plurality of reference frames, a predictive error signal between the predictive macroblock and an encoded macroblock and a motion vector are encoded for each macroblock, and a combination of predictive coefficients for the linear prediction is encoded for each frame.

In addition to the methods according to the 13th aspect, according to a 14th aspect of the present invention, there is provided a method in which the plurality of reference frames are past frames with

respect to a to-be-encoded frame.

According to a 15th aspect of the present invention, there is provided a video decoding method in which in decoding motion compensation predictive inter-frame encoded data by referring to a plurality of video frames for each macroblock, motion vector data and a predictive error signal which are encoded for each macroblock and a combination of predictive coefficients which encoded for each frame are received, a predictive macroblock is generated from the plurality of reference frames in accordance with the motion vector and predictive coefficients, and the generated predictive macroblock and the predictive error signal are added.

In addition to the method according to the fifth aspect, according to a 16th aspect of the present invention, there is provided a method in which the plurality of reference frames are past frames with respect to a to-be-encoded frame.

According to the methods of the 13th to 16th aspects of the present invention, since predictive coefficients can be set in an arbitrary time direction, the prediction efficiency can be improved by using an optimal combination of predictive coefficients on the encoding side not only when the amplitude of a picture signal changes over time as in the case of a fading picture but also when an arbitrary time jitter occurs

in the amplitude of a picture signal. In addition,
transmitting the above predictive coefficients upon
multiplexing them on encoded data allows the same
linear prediction as in encoding operation to be

5   performed in decoding operation, resulting in
high-efficiency predictive encoding.

According to the present invention, an improvement
in encoding efficiency can be achieved by a prediction
from a plurality of reference frames. However, as in

10   the case of B pictures in MPEG, a predictive from
temporally consecutive frames may be done by using a
plurality of past and future frames as reference
frames. In addition, as in the case of I and P
pictures in MPEG, only past frames may be used as

15   reference frames. Furthermore, a plurality of past P
and I pictures may be used as reference pictures.

This arrangement can realize encoding with picture
quality higher than that of conventional MPEG encoding.
In encoding P pictures using only past pictures, in

20   particular, the encoding efficiency can be greatly
improved as compared with the prior art by using a
plurality of past reference frames unlike in the prior
art. In encoding operation using no B pictures, there
is no need to provide a delay for rearrangement of

25   encoded frames. This makes it possible to realize
low-delay encoding. According to the present
invention, therefore, a greater improvement in encoding

efficiency can be attained even in low-delay encoding than in the prior art.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a block diagram showing a video encoding method according to the first embodiment of the present invention;

FIG. 2 is a block diagram showing a video decoding method according to the first embodiment of the present invention;

FIG. 3 is a view showing an inter-frame prediction relationship in video encoding and decoding methods according to the second embodiment of the present invention;

FIG. 4 is a view showing an inter-frame prediction relationship in video encoding and decoding methods according to the third embodiment of the present invention;

FIG. 5 is a view showing an inter-frame prediction relationship in video encoding and decoding methods according to the fourth embodiment of the present invention;

FIG. 6 is a view for explaining vector information encoding and decoding methods according to the fifth embodiment of the present invention;

FIG. 7 is a view for explaining vector information encoding and decoding methods according to the sixth embodiment of the present invention;

FIG. 8 is a view for explaining vector information encoding and decoding methods according to the seventh embodiment of the present invention;

FIG. 9 is a block diagram showing a video encoding apparatus for executing a video encoding method according to the eighth embodiment of the present invention;

FIG. 10 is a flow chart showing a sequence in a video encoding method according to the ninth embodiment of the present invention;

FIG. 11 is a view showing an example of the data structure of the picture header or slice header of to-be-encoded video data in the ninth embodiment;

FIG. 12 is a view showing an example of the data structure of a macroblock of to-be-encoded video data in the ninth embodiment;

FIG. 13 is a view showing the overall data structure of to-be-encoded video data according to the ninth embodiment;

FIG. 14 is a flow chart showing a sequence in a video decoding method according to the ninth embodiment;

FIG. 15 is a view for explaining temporal linear interpolation in the ninth embodiment;

FIG. 16 is a view for explaining temporal linear interpolation in the ninth embodiment;

FIG. 17 is a view showing an example of a linear

predictive coefficient table according to the first and eighth embodiments;

FIG. 18 is a view showing an example of a linear predictive coefficient table according to the first and eighth embodiments;

FIG. 19 is a view showing an example of a table indicating reference frames according to the first and eighth embodiments;

FIG. 20 is a block diagram showing a video encoding apparatus according to the 10th embodiment of the present invention;

FIG. 21 is a block diagram showing a video decoding apparatus according to the 10th embodiment of the present invention;

FIG. 22 is a view showing an example of a syntax indicating linear predictive coefficients according to the embodiment of the present invention;

FIG. 23 is a view showing an example of a table showing reference frames according to the embodiment of the present invention;

FIG. 24 is a view for explaining a motion vector information predictive encoding method according to the embodiment of the present invention;

FIGS. 25A and 25B are views for explaining a motion vector information predictive encoding method according to the embodiment of the present invention;

FIG. 26 is a block diagram showing the arrangement

of a video encoding apparatus according to the fourth
embodiment of the present invention;

FIG. 27 is a view for explaining an example of a
linear predictive coefficient determination method
according to the embodiment of the present invention;

FIG. 28 is a view for explaining an example of a
linear predictive coefficient determination method
according to the embodiment of the present invention;

FIG. 29 is a view for explaining an example of a
linear predictive coefficient determination method
according to the embodiment of the present invention;

FIG. 30 is a view for explaining an example of a
linear predictive coefficient determination method
according to the embodiment of the present invention;

FIG. 31 is a view for explaining an example of a
linear predictive coefficient determination method
according to the embodiment of the present invention;

FIG. 32 is a view for explaining a motion vector
search method according to the embodiment of the
present invention;

FIG. 33 is a view for explaining a motion vector
search method according to the embodiment of the
present invention;

FIG. 34 is a view for explaining a motion vector
encoding method according to the embodiment of the
present invention;

FIG. 35 is a view for explaining a motion vector

encoding method according to the embodiment of the present invention;

FIG. 36 is a view showing an inter-frame prediction relationship according to the embodiment of the present invention;

FIG. 37 is a view for explaining a motion vector encoding method according to the embodiment of the present invention;

FIG. 38 is a view for explaining a motion vector encoding method according to the embodiment of the present invention;

FIG. 39 is a view for explaining a motion vector encoding method according to the embodiment of the present invention;

FIG. 40 is a flow chart showing a procedure for video encoding according to the embodiment of the present invention;

FIG. 41 is a view for explaining a weighting prediction according to the embodiment of the present invention;

FIG. 42 is a view showing the data structure of a picture header or slice header according to the embodiment of the present invention;

FIG. 43 is a view showing the first example of the data structure of a weighting prediction coefficient table according to the embodiment of the present invention;

FIG. 44 is a view showing the second example of the data structure of a weighting prediction coefficient table according to the embodiment of the present invention;

5   FIG. 45 is a view showing the data structure of to-be-encoded video data according to the embodiment of the present invention; and

FIG. 46 is a flow chart showing a procedure for video decoding according to the present invention of

10   the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a block diagram showing a video encoding apparatus which executes a video encoding method according to an embodiment of the present invention.

15   According to this apparatus, a predictive macroblock generating unit 119 generates a predictive picture from the frame stored in a first reference frame memory 117 and the frame stored in a second reference frame memory 118. A predictive macroblock selecting unit 120

20   selects an optimal predictive macroblock from the predictive picture. A subtracter 110 generates a predictive error signal 101 by calculating the difference between an input signal 100 and a predictive signal 106. A DCT (Discrete Cosine Transform) unit 112

25   performs DCT for the predictive error signal 101 to send the DCT signal to a quantizer 113. The quantizer 113 quantizes the DCT signal to send the quantized

signal to a variable length encoder 114. The variable
length encoder 114 variable-length-encodes the
quantized signal to output encoded data 102. The
variable length encoder 114 encodes motion vector

5   information and prediction mode information (to be
described later) and outputs the resultant data
together with the encoded data 102. The quantized
signal obtained by the quantizer 113 is also sent to a
dequantizer 115 to be dequantized. An adder 121 adds

10   the dequantized signal and the predictive signal 106
to generate a local decoded picture 103. The local
decoded picture 103 is written in the first reference
frame memory 117.

In this embodiment, the predictive error signal

15   101 is encoded by a DCT transform, quantization, and
variable length encoding. However, the DCT trans-
formation may be replaced with a wavelet transform, or
the variable length encoding may be replaced with
arithmetic encoding.

20   In this embodiment, a local decoded picture of the
frame encoded immediately before the current frame is
stored in the first reference frame memory 117, and a
local decoded picture of the frame encoded further
before the above frame is stored in the second

25   reference frame memory 118. The predictive macroblock
generating unit 119 generates a predictive macroblock
signal 130, predictive macroblock signal 131,

predictive macroblock signal 132, and predictive macroblock signal 133. The predictive macroblock signal 130 is a signal extracted from only the picture in the first reference frame memory 117. The

5   predictive macroblock signal 131 is a macroblock signal extracted from only the picture in the second reference frame memory 118. The predictive macroblock signal 132 is a signal obtained by averaging the reference macroblock signals extracted from the first and second

10 reference frame memories. The predictive macroblock signal 133 is a signal obtained by subtracting the reference macroblock signal extracted from the second reference frame memory 118 from the signal obtained by doubling the amplitude of the reference macroblock

15 signal extracted from the first reference frame memory 117. These predictive macroblock signals are extracted from a plurality of positions in the respective frames to generate a plurality of predictive macroblock signals.

20   The predictive macroblock selecting unit 120 calculates the difference between each of the plurality of predictive macroblock signals generated by the predictive macroblock generating unit 119 and the to-be-encoded macroblock signal extracted from the

25 input video signal 100. The predictive macroblock selecting unit 120 then selects one of the predictive macroblock signals, which exhibits a minimum error for

each to-be-encoded macroblock, and sends the selected
one to the subtracter 110. The subtracter 110
calculates the difference between the selected
predictive macroblock signal and the input signal 100,
and outputs the predictive error signal 101. The
position of the selected predictive macroblock relative
to the to-be-encoded macroblock and the generation
method for the selected predictive macroblock signal
(one of the signals 130 to 133 in FIG. 1) are respec-
tively encoded as a motion vector and prediction mode
for each to-be-encoded block.

The variable length encoder 114 encodes the
encoded DCT coefficient data 102 obtained through the
DCT transformer 112 and quantizer 113 and side
information 107 containing the motion vector infor-
mation and prediction mode information output from the
predictive mode selecting unit 120, and outputs the
resultant data as encoded data 108. The encoded data
108 is sent out to a storage system or transmission
system (not shown).

In this case, when a video signal is formed of
a luminance signal and chrominance signals, the
predictive signal 106 is generated by applying the same
motion vector and prediction mode to the signal
components of the respective macroblocks.

FIG. 2 is a block diagram of a video decoding
apparatus, which executes a video decoding method

according to an embodiment of the present invention.
The video decoding apparatus in FIG. 2 receives and
decodes the data encoded by the video encoding
apparatus according to the first embodiment shown in
5   FIG. 1.

More specifically, a variable length decoding unit
214 decodes the variable length code of input encoded
data 200 to extract a predictive error signal 201 and
prediction mode information 202. The predictive error
10   signal 201 is subjected to dequantization and inverse
DCT in a dequantizing unit 215 and inverse DCT unit
216. The resultant data is added to a predictive
signal 206 to generate a decoded picture 203.

The decoded picture 203 is written in a first
15   reference frame memory 217. The predictive signal 206
is generated by a predictive macroblock generating unit
219 and predictive macroblock selecting unit 220 from
picture signals 204 and 205 in accordance with the
motion vector and prediction mode extracted from the
20   encoded data 200. The picture signal 204 is a picture
signal decoded immediately before the encoded data 200
and recorded on the first reference frame memory 217.
The picture signal 205 is a picture signal decoded
before the picture signal 204 and stored in a second
25   reference frame memory 218. The predictive signal 206
is the same predictive signal as the predictive
macroblock signal used at the time of encoding.

FIG. 3 schematically shows a relationship of an inter-frame prediction using two reference frames in video encoding and decoding methods according to the second embodiment of the present invention. FIG. 3

5 shows a to-be-encoded frame 302, a frame 301 immediately preceding the to-be-encoded frame 302, and a frame 300 further preceding the frame 302. While the frame 302 is encoded or decoded, a decoded picture of the frame 301 is stored in the first reference frame

10 memory 117 in FIG. 2 or the first reference frame memory 217 in FIG. 2, and the frame 300 is stored in the second reference frame memory 118 in FIG. 1 or the second reference frame memory 218 in FIG. 2.

A macroblock 305 in FIG. 3 is a to-be-encoded

15 macroblock, which is generated by using either or both of a reference macroblock 303 in the reference frame 300 and a reference macroblock 304 in the reference frame 301. Vectors 306 and 307 are motion vectors, which respectively indicate the positions of the

20 reference macroblocks 303 and 304. In encoding operation, a search is made for an optimal motion vector and prediction mode for the to-be-encoded macroblock 305. In decoding operation, a predictive macroblock signal is generated by using the motion

25 vector and prediction mode contained in the encoded data.

FIGS. 4 and 5 show examples of inter-frame

prediction using three or more reference frames according to the third and fourth embodiments of the present invention. FIG. 4 shows an example of using a plurality of past reference frames, i.e., a linear extrapolation prediction. FIG. 5 shows an example of using a plurality of past and future reference frames, i.e., a linear interpolation prediction.

Referring to FIG. 4, a frame 404 is a to-be-encoded frame, and frames 400 to 403 are reference frames for the frame 404. Reference numeral 413 in FIG. 4 denotes an encoded macroblock 413. In encoding operation, reference macroblocks (409 to 412 in FIG. 4) are extracted from the respective reference frames for each to-be-encoded macroblock in accordance with motion vectors (405 to 408 in FIG. 4) for the respective reference frames. A predictive macroblock is generated from a plurality of reference macroblocks by a linear extrapolation prediction.

A combination of a prediction mode and one of a plurality of reference macroblocks or a motion vector exhibiting a minimum predictive error in one of prediction modes for a predictive macroblock based on a linear prediction is selected. One combination of linear predictive coefficients is determined for each to-be-encoded frame from a change in average luminance between frames over time or the like. The determined combination of predictive coefficients is encoded as

header data for the to-be-encoded frame. The motion
vector of each macroblock, a prediction mode, and a
predictive error signal are encoded for each
macroblock.

5   In decoding operation, a combination of linear
predictive coefficients received for each frame is used
to generate a predictive macroblock for each macroblock
from a plurality of reference frames in accordance with
a motion vector and prediction mode information. The
10   encoded data is decoded by adding the predictive
macroblock to the predictive error signal.

       Referring to FIG. 5, a frame 502 is a
to-be-encoded frame, and frames 500, 501, 503, and 504
are reference frames. In the case shown in FIG. 5, in
15   encoding operation and decoding operation, the frames
500, 501, 503, 504, and 502 are rearranged in this
order. In the case of encoding, a plurality of local
decoded picture frames are used as reference frames.
In the case of decoding, a plurality of encoded frames
20   are used as reference frames. For a to-be-encoded
macroblock 511, one of reference macroblocks 509, 510,
512, and 513 or one of the predictive signals obtained
from them by linear interpolation predictions is
selected on a macroblock basis and encoded, as in the
25   embodiment shown in FIG. 4.

       FIG. 6 shows encoding and decoding methods for
motion vector information according to the fifth

embodiment of the present invention. Assume that in inter-frame encoding operation using a plurality of reference frames as in the embodiment shown in FIG. 3, a predictive macroblock signal is generated for each to-be-encoded macroblock by using a plurality of reference macroblock signals. In this case, a plurality of pieces of motion vector information must be encoded for each macroblock. Therefore, as the number of macroblocks to be referred to increases, the overhead for motion vector information to be encoded increases. This causes a deterioration in encoding efficiency. According to the method shown in FIG. 6, when a predictive macroblock signal is to be generated by extracting reference macroblock signals from two reference frames, respectively, one motion vector and the motion vector obtained by scaling the motion vector in accordance with the inter-frame distance are used.

A frame 602 is a to-be-encoded frame, and frames 601 and 600 are reference frames. Vectors 611 and 610 are motion vectors. Each black point indicates a pixel position in the vertical direction, and each white point indicates an interpolated point with a precision of 1/4 pixel. FIG. 6 shows a case wherein a motion compensation prediction is performed with a precision of 1/4 pixel. A motion compensation pixel precision is defined for each encoding scheme as 1 pixel, 1/2 pixel, 1/8 pixel, or the like. In general, a motion vector is

expressed by a motion compensation precision. A
reference picture is generally generated by inter-
polating the picture data of reference frames.

Referring to FIG. 6, with regard to a pixel 605 in
5   the to-be-encoded frame 602, a point 603 vertically
separated, by 2.5 pixels, from a pixel in the reference
frame 600 which corresponds to the pixel 605 is
referred to, and the motion vector 610 indicating a
shift of 2.5 pixels is encoded. On the other hand, a
10   motion vector extending from the pixel 605 to the
reference frame 601 is generated by scaling the encoded
motion vector 610 in accordance with the inter-frame
distance. In this case, the motion vector 611
extending from the pixel 605 to the frame 601 is a
15   vector corresponding to a shift of 2.5/2 = 1.25 pixels
from a pixel in the frame 601 corresponding to the
pixel 605 in consideration of the inter-frame distance.
A pixel 604 in the reference frame 601 is used as a
reference pixel for the pixel 605 in the to-be-encoded
20   frame 602.

Since motion vectors are scaled with the same
precision in encoding and decoding operations, only one
motion vector needs to be encoded for each macroblock
even when a to-be-encoded macroblock refers to a
25   plurality of frames. In this case, if the motion
vector scaling result does not exist on any of sampling
points with the motion compensation precision, the

scaled motion is rounded by rounding off its fractions to the nearest whole number.

FIG. 7 shows a motion vector information encoding and decoding methods according to the sixth embodiment of the present invention, which differ from those of the embodiment shown in FIG. 6. In the embodiment shown in FIG. 6, when the temporal moving speed of a video picture is constant, the overhead for motion vectors with respect to encoded data can be efficiently reduced. In a case wherein the temporal movement of a video picture is monotonous but the moving speed is not constant, the use of a simply scaled motion vector may lead to a decrease in prediction efficiency and hence a decrease in encoding efficiency. In the case shown in FIG. 7, as in the case shown in FIG. 6, a predictive pixel is generated from two reference frames 700 and 701 by using a pixel 706 as a reference pixel. Assume that a pixel 703 in the frame 700 and a pixel 705 in the frame 701 are referred to.

As in the fifth embodiment shown in FIG. 6, a motion vector 710 with respect to the frame 700 is encoded. A differential vector 720 between a motion vector 711 with respect to the frame 701 and the vector obtained by scaling the motion vector 710 is encoded. That is, the vector generated by scaling the motion vector 710 to 1/2 indicates a pixel 704 in the frame 701, and the differential vector 720 indicating the

difference amount between the predictive pixel 705 and the pixel 704 is encoded. In general, the magnitude of the above differential vector decreases with respect to a temporally monotonous movement. Even if, therefore,

5   the moving speed is not constant, the prediction efficiency does not decrease, and an increase in the overhead for a motion vector is suppressed. This makes it possible to perform efficient encoding.

FIG. 8 shows still other motion vector information

10   encoding and decoding methods according to the seventh embodiment of the present invention. In the embodiment shown in FIG. 8, a frame 803 is a to-be-encoded frame, and frames 801 and 800 are used as reference frames with a frame 802 being skipped. With respect to a

15   pixel 806, a pixel 804 in the reference frame 800 and a pixel 805 in the reference frame 801 are used as reference pixels to generate a predictive pixel.

As in the embodiment shown in FIG. 6 or 7, a motion vector 811 with respect to the reference frame

20   800 is encoded. A motion vector with respect to the reference frame 801 can also be generated by using the motion vector obtained by scaling the motion vector 811. In the case shown in FIG. 8, however, the motion vector 811 must be scaled to 2/3 in consideration of

25   the distance between the reference frame and the to-be-encoded frame. In the embodiment shown in FIG. 8 and other embodiments, in order to perform arbitrary

scaling, division is required because the denominator becomes an arbitrary integer other than a power of 2. Motion vectors must be scaled in both encoding operation and decoding operation. Division, in
5   particular, requires much cost and computation time in terms of both hardware and software, resulting in increases in encoding and decoding costs.

In the embodiment shown in FIG. 8, a motion vector 810 obtained by normalizing the to-be-encoded motion
10   vector 811 with the inter-frame distance is encoded. The differential vector between the motion vector obtained by scaling the normalized motion vector 810 and the original motion vector is encoded in accordance with the distance between the to-be-encoded frame and
15   each reference frame. That is, the reference pixel 804 is generated from the motion vector obtained by tripling the normalized motion vector 810 and a differential vector 820. The reference pixel 805 is generated from the motion vector obtained by doubling
20   the normalized motion vector 810 and a differential vector 821. The method shown in FIG. 8 prevents an increase in the encoding overhead for motion vectors without decreasing the prediction efficiency. In addition, since scaling of a motion vector can be done
25   by multiplication alone, increases in the computation costs for encoding and decoding operations can also be suppressed.

FIG. 9 is a block diagram of a video encoding apparatus, which executes a video encoding method according to the eighth embodiment of the present invention. In the eighth embodiment, a fade detecting

5   unit 900 for an input picture 900 is added to the video encoding apparatus according to the macroblock shown in FIG. 1. The fade detecting unit 900 calculates an average luminance value for each frame of the input video signal. If a change in luminance over time has a

10   predetermined slope, it is determined that the picture is a fading picture. A result 901 is notified to a predictive mode selecting unit 120.

If the fade detecting unit 900 determines that the input picture is a fading picture, a prediction mode is

15   limited to a prediction from one reference frame or a prediction based on linear extrapolation or linear interpolation of a plurality of reference frames. An optimal motion vector and prediction mode are then determined for each macroblock. The first flag

20   indicating the determined motion vector and prediction mode is written in the header of a macroblock, and a predictive error signal is encoded. Meanwhile, the second flag indicating a possible prediction mode combination is written in the header data of the frame.

25   If the fade detecting unit 900 determines that the picture is not a fading picture, a prediction mode is limited to a prediction from one reference frame or a

prediction based on the average value of a plurality of reference frames. An optimal motion vector and prediction mode are then determined. The motion vector, prediction mode, and predictive error signal 101 are encoded.

When the data encoded by the method of the embodiment shown in FIG. 9 is to be decoded, a prediction mode for each macroblock is determined from the first and second flags indicating a prediction mode. A predictive macroblock signal is generated from a motion vector sent for each macroblock and the determined prediction mode. The encoded predictive error signal is decoded and added to the predictive signal to decode the encoded data. This method can reduce the encoding overhead for prediction mode information.

A sequence in a video encoding method according to the ninth embodiment of the present invention will be described with reference to FIG. 10.

To-be-encoded video frames are input one by one to a video encoding apparatus (not shown). A fading picture is detected for each slice formed from an entire frame or a plurality of pixel blocks in the frame on the basis of a change in intra-frame average luminance value over time or the like (step S1). A single frame prediction mode or linear sum prediction mode is selected for each pixel block in a frame. The

single frame prediction mode is a prediction mode of
generating a predictive pixel block signal by selecting
one optimal reference frame from a plurality of
reference frames.   The linear sum prediction mode is a
5   prediction mode of generating a predictive pixel block
by a prediction based on the linear sum of two
reference pixel block signals.

In the linear sum prediction mode, when an input
video picture is detected as a fading picture, a
10   temporal linear interpolation (interpolation or
extrapolation based on an inter-frame time distance)
prediction is performed to generate a predictive pixel
block.   If the input video picture is not a fading
picture, a predictive picture block is generated from
15   the average value of two reference pixel block signals.
Second to-be-encoded mode information indicating
whether a linear sum prediction using a plurality of
frames is an average value prediction or temporal
linear interpolation prediction is encoded as the
20   header data of a frame (picture) or slice (step S2).

It is checked whether or not the input video
picture is a fading picture (step S3).   If it is
determined that the input video picture is a fading
picture, an encoding mode which exhibits a higher
25   encoding efficiency and the small number of encoded
bits is determined for each pixel block from an
encoding mode of selecting a single prediction block

from a plurality of reference frames (step S5) and an encoding mode based on a temporal linear interpolation prediction (step S4) (step S8).

A macroblock header containing the first encoding mode information indicating the single frame prediction mode or linear sum prediction mode and other pieces of information concerning the selected encoding mode (e.g., the identification information of a reference frame to be used for a prediction and motion vector) is encoded (step S10). Finally, the differential signal (predictive error signal) between the selected predictive block signal and the signal of the to-be-encoded block is encoded (step S11), and the encoded data is output (S12).

If NO in step S3, an optimal encoding mode is selected from the single frame prediction mode (step S6) and the average value prediction mode (step S7) (step S9). Subsequently, in the same manner, encoding of the information concerning the encoding mode (step S10) and encoding of the differential signal (step S11) are performed.

When each block in a frame or slice is encoded in accordance with the fade detection result in step S1, and encoding of all the pixel blocks in one frame (picture) or one slice is completed (step S12), fade detection is performed with respect to the frame or slice to be encoded next (step S1). Encoding is

performed through similar steps.

According to the above description, one frame is encoded as one picture. However, one frame may be encoded as one picture on a field basis.

5   FIGS. 11 and 12 show the structure of to-be-encoded video data according to this embodiment. FIG. 11 shows part of the data structure, which includes the header data of a picture or slice. FIG. 12 shows part of macroblock data. In the header

10   area of the picture or slice, the following information is encoded: information "time_info_to_be_displayed" concerning the display time of a to-be-encoded frame, and flag "linear_weighted_prediction_flag" which is the second encoding mode information indicating whether or not an average value prediction is selected. In this

15   not an average value prediction is selected. In this case, "linear_weighted_prediction_flag" = 0 represents an average value prediction, and "linear_weighted_prediction_flag" = 1 represents a temporal linear interpolation prediction.

20   The encoded data of a picture or slice contains a plurality of encoded macroblock data. Each macroblock data has a structure like that shown in FIG. 12. In the header area of the macroblock data, information (first encoding mode information) indicating a single

25   frame prediction based on a selected single frame or a prediction based on the linear sum of a plurality of frames is encoded as "macroblock_type", together with

selection information concerning a reference frame, motion vector information, and the like.

FIG. 13 schematically shows the overall time-series structure of the to-be-encoded video data

5 including the structure shown in FIGS. 11 and 12. In the head of the to-be-encoded data, information of a plurality of encoding parameters which remain constant within one encoding sequence, such as a picture size, is encoded as a sequence header (SH).

10 Each picture frame or field is encoded as a picture, and each picture is sequentially encoded as a combination of a picture header (PH) and picture data (Picture data). In the picture header (PH), informa-tion "time_info_to_be_displayed" concerning the display

15 time of the to-be-encoded frame shown in FIG. 11 and second encoding mode information "linear_weighted_prediction_flag" are respectively encoded as DTI and LWP. The picture data is divided into one or a plurality of slices (SLC), and the data

20 are sequentially encoded for each slice. In each slice SLC, an encoding parameter associated with each pixel block in the slice is encoded as a slice header (SH), and one or a plurality of macroblock data (MB) are sequentially encoded following the slice header SH.

25 The macroblock data MB contains encoded data MBT of "macroblock_type" which is the first encoding mode information shown in FIG. 12, the encoded information

concerning encoding of each pixel in the macroblock,
e.g., motion vector information (MV), and the
orthogonal transform coefficient (DCT) obtained by
performing an orthogonal transform (e.g., a discrete
cosine transform) of the to-be-encoded pixel signal or
predictive error signal and encoding it.

In this case, second encoding mode information
"linear_weighted_prediction_flag" contained in the
picture header HP may be encoded by the slice header SH
for each slice.

A sequence in a video decoding method according to
the ninth embodiment will be described below with
reference to FIG. 14.

In the video encoding method of this embodiment,
encoded data which is encoded by the video encoding
method shown in FIG. 10 and has a data structure like
that shown in FIGS. 11 and 12 is input and decoded.
The header information of a picture or slice contained
in the input coded data is decoded. More specifically,
information "time_info_to_be_displayed" concerning the
display time of a to-be-encoded frame and second
encoding mode information
"linear_weighted_prediction_flag" are decoded (step
S30).

In addition, the header information of each
macroblock in the picture or slice is decoded. That
is, "macroblock_type" including the identification

information of a reference frame, motion vector information, and first encoding mode information and the like are decoded (step S31).

If the decoded first encoding mode information indicates a single frame prediction, a predictive block signal is generated in accordance with the identification information of a reference frame and prediction mode information such as motion vector information (step S34). Assume the first encoding mode information indicates a prediction based on the linear sum of a plurality of frames. In this case, in accordance with the decoded second encoding mode information (step S33), a predictive signal is generated by either an average prediction method (step S35) or a temporal linear interpolation prediction method (step S36).

The encoded predictive error signal is decoded and added to the predictive signal. With this operation, a decoded picture is generated (step S37). When each macroblock in the picture or slice is sequentially decoded, starting from each macroblock head, and all the macroblocks in the picture or slice are completely decoded (step S38), decoding is consecutively performed again, starting from a picture or slice header.

As described above, according to this embodiment, information concerning encoding modes is divided into the first encoding mode information indicating a single frame prediction or a prediction based on the linear

sum of a plurality of frames, and the second encoding
mode information indicating whether a prediction based
on a linear sum is a temporal linear interpolation
prediction or an average prediction. The first
5   encoding mode information is encoded for each
macroblock. The second encoding mode information is
encoded for each picture or slice. This makes it
possible to reduce the encoding overhead for
to-be-encoded mode information while maintaining the
10   encoding efficiency.

     That is, the second encoding mode information
indicates broad-based characteristics in a frame such
as a fading picture. If, therefore, the second
encoding mode information is encoded for each slice or
15   frame, an increase in code amount required to encode
the encoding mode information itself can be suppressed
while a great deterioration in encoding efficiency can
be suppressed as compared with the method of encoding
the information for each macroblock.

20   Encoding the first encoding mode information for
each macroblock makes it possible to determine an
appropriate mode in accordance with the individual
characteristics of each pixel block (e.g., a picture
that partly appears and disappears over time). This
25   makes it possible to further improve the encoding
efficiency.

     In this embodiment, since the encoding frequencies

of the first encoding mode information and second

encoding mode information are determined in

consideration of the characteristics of video pictures,

high-efficiency, high-picture-quality encoding can be

5 done.

A temporal linear interpolation prediction in this

embodiment will be described in detail next with

reference to FIGS. 15 and 16.

Reference symbols F0, F1, and F2 in FIG. 15 and

10 reference symbols F0, F2, and F1 in FIG. 16 denote

temporally consecutive frames. Referring FIG. 15 and

16, the frame F2 is a to-be-encoded or to-be-decoded

frame, and the frames F0 and F1 are reference frames.

Assume that in the embodiment shown in FIGS. 15 and 16,

15 a given pixel block in a to-be-encoded frame or a

to-be-decoded frame is predicted from the linear sum of

two reference frames.

If the linear sum prediction is an average value

prediction, a predictive pixel block is generated from

20 the simple average of the reference blocks extracted

from the respective reference frames. Letting ref0 and

ref1 be the reference pixel block signals extracted

from the frames F0 and F1, respectively, each of

predictive pixel block signals pred2 in FIGS. 15 and 16

25 is given by

$$pred2=(ref0 + ref1) / 2 \qquad (15)$$

If the linear sum prediction is a temporal linear

interpolation prediction, a linear sum is calculated in accordance with the time difference between a to-be-encoded frame or a to-be-decoded frame and each reference frame. As shown in FIG. 11, information "time_info_to_be_displayed" concerning a display time in a picture or slice header area is encoded for each to-be-encoded frame. At the time of decoding, the display time of each frame is calculated on the basis of this information. Assume that the display times of the frames F0, F1, and F2 are respectively represented by Dt0, Dt1, and Dt2.

The embodiment shown in FIG. 15 exemplifies a linear extrapolation prediction for predicting the current frame from two past frames. The embodiment shown in FIG. 16 exemplifies a linear interpolation prediction from future and past frames. Referring to FIGS. 15 and 16, letting Rr be the time distance between two reference frames, and Rc be the time distance from the earliest reference frame with respect to a to-be-encoded frame to the to-be-encoded frame, the time distance Rr is given by

$$Rr=Dt1-Dt0, \quad Rc=Dt2-Dt0 \tag{16}$$

In both the cases shown in FIGS. 15 and 16, the linear extrapolation prediction and liner interpolation prediction based on the above time distances are calculated by

$$pred2=\{ (Rr-Rc)*ref0+Rc*ref1 \} / Rr \tag{17}$$

Equation (17) can be transformed into equation (18):

$$Pred2 = ref0 + (ref1 - ref0) * Rc/Rr \qquad (18)$$

In a picture such as a fading picture or cross-fading picture whose signal amplitude monotonously varies over time between frames, the time jitter in signal amplitude can be linearly approximated within a very short period of time (e.g., equivalent to three frames). As in this embodiment, therefore, a more accurate predictive picture can be generated by performing temporal linear interpolation (linear extrapolation or linear interpolation) in accordance with the time distance between a to-be-encoded frame and each of two reference frames. As a consequence, the inter-frame prediction efficiency improves. This makes it possible to reduce the generated code amount without degrading the picture quality. Alternatively, this makes it possible to perform higher-quality encoding with the same bit rate.

The above encoding and decoding processing in the present invention may be implemented by hardware, or part or all of the processing can be implemented by software.

FIGS. 17 and 18 each show an example of a predictive coefficient table used for one of the prediction modes in the first and eighth embodiments which is based on the linear sum of a plurality of reference frames. Predictive coefficients change on

the macroblock basis in the first embodiment, and
change on the frame basis in the eighth embodiment.
There is a combination of two coefficients: "average"
and "linear extrapolation".

5   An index (Code_number) shown in FIGS. 17 and 18 is
encoded as header data for each macroblock or frame.
In the eighth embodiment, since a linear predictive
coefficient is constant for each frame, encoding may be
performed by using only the header data of a frame.   In

10   the predictive coefficient table shown in FIG. 17, the
numerical values of the coefficients are explicitly
defined.   The predictive coefficient table shown in
FIG. 18 indicates "average" or "linear prediction
(interpolation or extrapolation)".   By encoding such

15   indexes, the amount of information to be encoded can be
reduced, and hence the encoding overhead can be reduced
as compared with the case wherein linear predictive
coefficients are directly encoded.

       FIG. 19 is a table indicating a combination of

20   reference frames (Reference_frame) associated with
various prediction modes in the first and eighth
embodiments of the present invention.   Referring to
FIG. 19, Code_number = 0 indicates a combination of
reference frames in a prediction mode from an

25   immediately preceding frame (one frame back);
Code_number = 1, in a prediction mode two frames back;
and Code_number = 2, in a prediction mode based on the

linear sum of frames one frame back and two frames back. In the case of Code_number = 2, the prediction mode using the above linear predictive coefficients is used.

In the first and eighth embodiments, the combinations of reference frames can be changed on the macroblock basis, and the indexes in the table in FIG. 19 are encoded on the macroblock basis.

FIGS. 20 and 21 show the arrangements of a video encoding apparatus and video decoding apparatus according to the 10th embodiment of the present invention. In the first and eighth embodiments, a prediction is performed on the basis of the linear sum of a maximum of two reference frames. In contrast to this, the 10th embodiment can perform a prediction based on selection of one specific frame for each macroblock by using three or more reference frames or the linear sum of a plurality of reference frames.

The video encoding apparatus shown in FIG. 20 includes reference frame memories 117, 118, and 152 corresponding to the maximum reference frame count (n). Likewise, the video decoding apparatus in FIG. 21 includes reference frame memories 217, 218, and 252 corresponding to the maximum reference frame count (n). In this embodiment, in a prediction based on a linear sum, each of predictive macroblock generators 151 and 251 generates a predictive picture signal by computing

the sum of the products of predictive coefficients W1 to Wn and reference macroblocks extracted from the respective reference frames and shifting the result to the right by Wd bits. The reference frames to be selected can be changed for each macroblock, and the linear predictive coefficients can be changed for each frame. A combination of linear predictive coefficients is encoded as header data for a frame, and the selection information of reference frames is encoded as header data for each macroblock.

FIG. 22 shows a data syntax for encoding by using a linear predictive coefficient as a header for a frame according to this embodiment. In encoding linear predictive coefficients, the maximum number of reference frames is encoded first as Number_Of_Max_References. WeightingFactorDenominatorExponent (Wd in FIGS. 20 and 21) indicating the computation precision of linear predictive coefficients is then encoded. Coefficients WeightingFactorNumerator[i] (W1 to Wn in FIGS. 20 and 21) corresponding to the respective reference frames equal to Number_Of_Max_References are encoded. The linear predictive coefficient corresponding to the ith reference frame is given by

$$W_i / 2^{Wd} \tag{19}$$

FIG. 23 shows a table indicating a combination of reference frames to be encoded for each macroblock

according to this embodiment. Code_number = 0
indicates a prediction based on the linear sum of all
reference frames. Code_number = 1 indicates that a
reference frame is one specific frame and that a frame

5   a specific number of frames back is used as a reference
frame. A prediction based on the linear sum of all
reference frames is performed by using the predictive
coefficients shown in FIG. 22. In this case, some of
the predictive coefficients are set to 0 so that a

10   linear prediction based on a combination of arbitrary
reference frames can be switched on the frame basis in
the linear prediction mode.

        In this embodiment of the present invention, a
motion vector or differential vector is encoded by

15   using the spatial or temporal correlation between
motion vectors in the following manner to further
decrease the motion vector code amount.

        A motion vector compression method using a spatial
correlation will be described first with reference to

20   FIG. 24. Referring to FIG. 24, reference symbols A, B,
C, D, and E denote adjacent macroblocks in one frame.
When a motion vector or differential vector of the
macroblock A is to be encoded, a prediction vector is
generated from the motion vectors of the adjacent

25   macroblocks B, C, D, and E. Only the error between the
motion vector of the prediction vector and that of the
macroblock A is encoded. On the decoding side, a

prediction vector is calculated in the same manner as in an encoding operation. The motion vector or differential vector of the macroblock A is generated by adding this prediction vector to the encoded error

5   signal.

Encoding a motion vector error by variable length encoding or arithmetic encoding can compress the picture with high efficiency. A motion vector can be predicted by using, for example, the median or average

10   value of the motion vectors of the macroblocks B, C, D, and E as a prediction vector.

A motion vector compression method using a temporal correlation will be described with reference to FIGS. 25A and 25B. FIGS. 25A and 25B show two

15   consecutive frames (F0, F1). Referring to FIGS. 25A and 25B, reference symbols A, B, C, D, and E denote adjacent macroblocks in the frame F1; and a, b, c, d, and e, macroblocks at the same positions as those of the macroblocks A, B, C, D, and E in the frame F0.

20   When the motion vector or differential vector of the macroblock A is to be encoded, the motion vector of the macroblock a at the same position as that of the macroblock A is set as a prediction vector. The motion vector information can be compressed by encoding only

25   the error between this prediction vector and the vector of the macroblock A.

A three-dimensional prediction is further made on

the motion vector of the macroblock A by using a spatiotemporal correlation and the motion vectors of the macroblocks B, C, D, and E in the frame F1 and of the macroblocks a, b, c, d, and e in the frame F0. The

5   motion vector can be compressed with higher efficiency by encoding only the error between the prediction vector and the to-be-encoded vector.

A three-dimensional prediction on a motion vector can be realized by generating a prediction vector from

10   the median value, average value, or the like of a plurality of spatiotemporally adjacent motion vectors.

An embodiment of macroblock skipping according to the present invention will be described. Assume that in motion compensation predictive encoding, there are

15   macroblocks in which all prediction error signals become 0 by DCT and quantization. In this case, in order to reduce the encoding overhead, macroblocks that satisfy predefined, predetermined conditions are not encoded, including the header data of the macroblocks,

20   e.g., prediction modes and motion vectors. Of the headers of video macroblocks, only those of macroblocks corresponding to the number of macroblocks that are consecutively skipped are encoded. In a decoding operation, the skipped macroblocks are decoded in

25   accordance with a predefined, predetermined mode.

In the first mode of macroblock skipping according to the embodiment of the present invention, macroblock

skipping is defined to satisfy all the following conditions that a reference frame to be used for a prediction is a predetermined frame, all motion vector elements are 0, and all prediction error signals are 0.

5 In a decoding operation, a predictive macroblock is generated from predetermined reference frames as in the case wherein a motion vector is 0. The generated predictive macroblock is reconstructed as a decoded macroblock signal.

10 Assume that setting the linear sum of two immediately preceding frames as a reference frame is a skipping condition for a reference frame. In this case, macroblock skipping can be done even for a picture whose signal intensity changes over time, like

15 a fading picture, thereby improving the encoding efficiency. Alternatively, the skipping condition may be changed for each frame by sending the index of a reference frame serving as a skipping condition as the header data of each frame. By changing the frame

20 skipping condition for each frame, an optimal skipping condition can be set in accordance with the properties of an input picture, thereby reducing the encoding overhead.

In the second mode of macroblock skipping

25 according to the embodiment of the present invention, a motion vector is predictively encoded. Assume that a macroblock skipping condition is that the error signal

of a motion vector is 0. The remaining conditions are
the same as those for macroblock skipping in the first
mode described above. In the second mode, in decoding
a skipped macroblock, a prediction motion vector is

5   generated first. A prediction picture is generated
from predetermined reference frames by using the
generated prediction motion vector, and the decoded
signal of the macroblock is generated.

In the third mode of macroblock skipping according

10   to the embodiment of the present invention, a skipping
condition is that to-be-encoded motion vector
information is identical to the motion vector
information encoded in the immediately preceding
macroblock. To-be-encoded motion vector information is

15   a prediction error vector when a motion vector is to be
predictively encoded, and is a motion vector itself
when it is not predictively encoded. The remaining
conditions are the same as those in the first mode
described above.

20   In the third mode of macroblock skipping, when a
skipped macroblock is to be decoded, the to-be-encoded
motion vector information is regarded as 0, and the
motion vector is reconstructed. A prediction picture
is generated from predetermined reference frames in

25   accordance with the reconstructed motion vector, and
the decoded signal of the macroblock is generated.

Assume that in the fourth mode of macroblock

skipping, a combination of reference frames to be used for a prediction is identical to that for the immediately encoded macroblock. The remaining skipping conditions are the same as those in the first mode described above.

Assume that in the fifth mode of macroblock skipping, a combination of reference frames used for a prediction is identical to that for the immediately encoded macroblock. The remaining skipping conditions are the same as those in the first mode described above.

Assume that in the sixth mode of macroblock skipping, a combination of reference frames used for a prediction is identical to that for the immediately encoded macroblock. The remaining skipping conditions are the same as those in the third mode described above.

According to the skipping conditions in either of the first to sixth modes described above, a reduction in encoding overhead and highly efficient encoding can be realized by efficiently causing macroblock skipping by using the property that the correlation of movement between adjacent macroblocks or change in signal intensity over time is high.

FIG. 26 shows an embodiment in which a linear predictive coefficient estimator 701 is added to the video encoding apparatus according to the embodiment

shown in FIG. 20. In the linear predictive coefficient estimator 701, predictive coefficients for a linear prediction are determined from a plurality of reference frames in accordance with the distance from each

5   reference frame and a video frame, a temporal change in DC component within an input frame, and the like. A plurality of embodiments associated with determination of specific predictive coefficients will be described below.

10   FIG. 27 shows a prediction method of predicting a frame from the linear sum of two past frames. Reference frames F0 and F1 are used for a video frame F2. Reference symbols Ra and Rb denote the inter-frame distances between the respective reference frames F0

15 and F1 and the video frame F2. Let W0 and W1 be linear predictive coefficients for the reference frames F0 and F1. A combination of first linear predictive coefficients is (0.5, 0.5). That is, this combination can be obtained from the simple average of the two

20 reference frames. Second linear predictive coefficients are determined by linear extrapolation in accordance with the inter-frame distance. In the case shown in FIG. 27(20), linear predictive coefficients are given by equation (20). If, for example, the frame

25 intervals are constant, Rb = 2*Ra, and linear predictive coefficients given by:

$$(W_0, W_1) = \left(\frac{-Ra}{Rb - Ra} , \frac{Rb}{Rb - Ra} \right) \tag{20}$$

are (W0, W1) = (-1, 2).

According to equation (20), even if the inter-frame distance between each reference frame and the video frame arbitrarily changes, a proper linear

5   prediction can be made. Even if, for example, variable-frame-rate encoding is performed by using frame skipping or the like or two arbitrary past frames are selected as reference frames, high prediction efficiency can be maintained. In an encoding

10   operation, one of the first and second predictive coefficients may be permanently used or the first or second predictive coefficients may be adaptively selected. As a practical method of adaptively selecting predictive coefficients, a method of

15   selecting predictive coefficients by using the average luminance value (DC value) in each frame may be used.

Assume that the average luminance values in the frames F0, F1, and F2 are DC(F0), DC(F1), and DC(F2), respectively. As for DC components of a intra-frame,

20   the magnitudes of prediction errors obtained by using the respective linear predictive coefficients are calculated by the equations (21) and (22):

$$\left| DC(F2) - \left(\frac{DC(F0) + DC(F1)}{2} \right) \right| \quad (21)$$

25

$$\left| DC(F2) - \left(\frac{Rb}{Rb - Ra} DC(F1) - \frac{Ra}{Rb - Ra} DC(F0) \right) \right| \quad (22)$$

If the value of mathematic expression (21) is

smaller than that of mathematic expression (22), the
first predictive coefficient is selected. If the value
of mathematic expression (22) is smaller than that of
mathematic expression (21), the second predictive

5   coefficient is selected. By changing these predictive
coefficients for each video frame, an optical linear
prediction can be made in accordance with the
characteristics of a video signal. Efficient linear
prediction can also be made by determining the third

10   and fourth predictive coefficients by using the ratios
of DC values in the frames according to equation (23)
or (24):

$$\left(W_0, W_1\right) = \left(\frac{1}{2} \bullet \frac{DC(F2)}{DC(F0)}, \frac{1}{2} \bullet \frac{DC(F2)}{DC(F1)}\right) \tag{23}$$

15

$$\left(W_0, W_1\right) = \left(\frac{-Ra}{Rb - Ra} \bullet \frac{DC(F2)}{DC(F0)}, \frac{Rb}{Rb - Ra} \bullet \frac{DC(F2)}{DC(F1)}\right) \tag{24}$$

The third linear predictive coefficient given by
equation (23) is the weighted mean calculated in
consideration of the ratios of the DC values in the

20   frames. The fourth linear predictive coefficient given
by equation (24) is the linear predictive coefficient
calculated in consideration of the ratios of the DC
values in the frames and the inter-frame distances. In
the use of the above second to fourth linear predictive

25   coefficients, linear predictions require division.
However, matching the computation precision at the time
of encoding with that at the time of decoding allows a
linear prediction based on multiplications and bit

shifts without any division.

A practical syntax may be set such that each linear predictive coefficient is expressed by a denominator to a power of 2 and an integer numerator, as in the case shown in FIG. 22. FIG. 28 shows a method of predicting a frame from the linear sum of two temporally adjacent frames. Referring to FIG. 28, reference symbol F1 denotes a to-be-encoded frame; F0 and F2, reference frames; and Ra and Rb, the inter-frame distances between the respective reference frames and the video frame. In addition, linear predictive coefficients for the reference frames F0 and F2 are represented by W0 and W2, respectively. The intra-frame average values of the luminance values of the respective frames are represented by DC(F0), DC(F1), and DC(F2), respectively. Four types of predictive coefficient combinations like those in FIG. 27(20) are given by equations (25) to (28):

$$(W_0, W_2) = (0.5, 0.5) \tag{25}$$

$$(W_0, W_2) = \left(\frac{Ra}{Rb + Ra}, \frac{Rb}{Rb + Ra} \right) \tag{26}$$

$$(W_0, W_2) = \left(\frac{1}{2} \bullet \frac{DC(F1)}{DC(F0)}, \frac{1}{2} \bullet \frac{DC(F1)}{DC(F2)} \right) \tag{27}$$

$$(W_0, W_2) = \left(\frac{Ra}{Rb + Ra} \bullet \frac{DC(F1)}{DC(F0)}, \frac{Rb}{Rb + Ra} \bullet \frac{DC(F1)}{DC(F2)} \right) \tag{28}$$

Equation (25) represents a simple average prediction; equation (26), a weighted mean prediction

based on an inter-frame distances, equation (27), a weighed mean prediction based on the ratios of the DC values; and equation (28), a weighting prediction based on the ratios of the DC values and the inter-frame

5   distances.

FIG. 29 shows a method of performing a predetermined prediction based on the linear sum of three past frames. Reference symbols F0, F1, and F2 denote reference frames; F3, a video frame; and Rc, Rb,

10   and Ra, the inter-frame distances between the respective reference frames F0, F1, and F2 and the video frame F3. In the case shown in FIG. 29 as well, a plurality of linear predictive coefficient combinations can be conceived. The following is a

15   specific example. Assume that the linear predictive coefficients for the respective reference frames are represented by W0, W1, and W2.

A combination of first predictive coefficients is given by equation (29). The first predictive

20   coefficients are used for a simple average prediction based on three reference frames. A prediction picture F_3^{012} based on the first predictive coefficient combination is represented by the equation (30):

25
$$(W_0, W_1, W_2) = \left(\frac{1}{3}, \frac{1}{3}, \frac{1}{3} \right) \tag{29}$$

$$aF_3^{012} = \frac{1}{3} (F1 + F2 + F3) \tag{30}$$

The second, third, and fourth predictive

coefficients are coefficients for performing an extrapolation prediction based on linear extrapolation by selecting two frames from the three reference frames as in the case of a prediction based on equation (20). Letting eF_3^{12} be a prediction picture of the video frame F3 which is predicted from the reference frames F2 and F1, eF_3^{02} be a prediction picture of the video frame f3 which is predicted from the reference frames F2 and F0, and eF_3^{01} be a prediction picture of the video frame F3 which is predicted from the reference frames F1 and F0, these prediction pictures are respectively represented by equations (31), (32) and (33):

$$eF_3^{12} = \frac{Rb}{Rb - Ra} F2 - \frac{Ra}{Rb - Ra} F1 \tag{31}$$

$$eF_3^{02} = \frac{Rc}{Rc - Ra} F2 - \frac{Ra}{Rc - Ra} F0 \tag{32}$$

$$eF_3^{01} = \frac{Rc}{Rc - Rb} F1 - \frac{Rb}{Rc - Rb} F0 \tag{33}$$

Letting eF_3^{012} be a prediction value obtained by averaging the values given by equations (31) to (33), the prediction value eF_3^{012} can be given as the fifth predictive coefficient by the equation (34):

$$eF_3^{012} = \frac{1}{3} \frac{2RaRb - RaRc - RbRc}{(Rc - Ra)(Rc - Rb)} F0$$
$$+ \frac{1}{3} \frac{RaRb - 2RaRc + RbRc}{(Rc - Rb)(Rb - Ra)} F1 \tag{34}$$
$$+ \frac{1}{3} \frac{- RaRb - RaRc + 2RbRc}{(Rc - Ra)(Rb - Ra)} F2$$

One of the first to fifth linear predictive

coefficients may be used. Alternatively, intra-frame average luminance values DC(F0), DC(F1), DC(F2), and DC(F3) of the frames F0, F1, F2, and F3 may be calculated, and the intra-frame average luminance value of the video frame F3 may be predicted by using each of the above five predictive coefficients. One of the predictive coefficients which exhibits a minimum prediction error may be selectively used for each video frame. The use of the latter arrangement allows automatic selection of an optimal linear prediction on the frame basis in accordance with the properties of an input picture and can realize high-efficiency encoding.

In addition, the predictive coefficients obtained by multiplying the first to fifth linear predictive coefficients by the ratios of the average luminance values of the respective frames may be used. If, for example, the first predictive coefficient is multiplied by the ratios of the average luminance values, a predictive coefficient is given by equation (35) be low. This applies to the remaining predictive coefficients.

$$\left(w_0, w_1, w_2 \right) = \left(\frac{1}{3} \bullet \frac{DC(F3)}{DC(F0)}, \frac{1}{3} \bullet \frac{DC(F3)}{DC(F1)}, \frac{1}{3} \bullet \frac{DC(F3)}{DC(F2)} \right) \quad (35)$$

FIG. 30 shows a method of performing a prediction based on the linear sum of two past frames and one future frame. Reference symbols F0, F1, and F3 denote reference frames; F2, a video frame; and Rc, Rb, and

Ra, the inter-frame distances between the reference
frames F0, F1, and F3 and the video frame. In this
case, as in the case shown in FIG. 29, a plurality of
predictive coefficient combinations can be determined

5   by using the ratios of the inter-frame distances and
the DC values in the respective frames. In addition,
an optimal predictive coefficient combination can be
determined from the prediction errors of the DC values
in the frames.

10   Linear prediction expressions or predictive
coefficients corresponding to equations (30) to (35) in
the prediction method in FIG. 30 are expressed by the
equations (36) to (41):

15
$$aF_2^{013} = \frac{1}{3}\left(F0 + F1 + F3\right) \tag{36}$$

$$eF_2^{13} = \frac{Rb}{Rb + Ra}\,F3 + \frac{Ra}{Rb + Ra}\,F1 \tag{37}$$

$$eF_2^{03} = \frac{Rc}{Rc + Ra}\,F3 + \frac{Ra}{Rc + Ra}\,F0 \tag{38}$$

20
$$eF_2^{01} = \frac{Rc}{Rc - Rb}\,F1 - \frac{Rb}{Rc - Rb}\,F0 \tag{39}$$

$$eF_2^{013} = \frac{1}{3}\,\frac{1 - 2RaRb + RaRc - RbRc}{(Rc + Ra)\,(Rc - Rb)}\,F0$$
$$+ \frac{1}{3}\,\frac{1 - RaRb + 2RaRc + RbRc}{(Rc - Rb)\,(Rb + Ra)}\,F1 \tag{40}$$
$$+ \frac{1}{3}\,\frac{1\;RaRb + RaRc + 2RbRc}{(Rc + Ra)\,(Rb + Ra)}\,F3$$

25
$$\left(w_0,\ w_1,\ w_3\right) = \left(\frac{1}{3}\bullet\frac{DC(F2)}{DC(F0)},\ \frac{1}{3}\bullet\frac{DC(F2)}{DC(F1)},\ \frac{1}{3}\bullet\frac{DC(F2)}{DC(F3)}\right) \tag{41}$$

FIG. 31 shows the first example of a motion vector

search in video encoding according to the embodiment of
the present invention. FIG. 32 shows a motion vector
search method in a case wherein a prediction is made by
using two consecutive frames as reference frames, and
5   one representative motion vector is encoded, as shown
in FIG. 6. Reference symbol F2 in figure denotes a
video frame; and F0 and F1, reference frames.
Reference numeral 10 denotes a video macroblock; and
12, 14, 16, and 18, some reference macroblock
10   candidates in the reference frames.

In order to obtain an optimal motion vector for
the macroblock 10, motion vector candidates (motion
vector candidates 11 and 15 in FIG. 31) for the
reference frame F1 within a motion vector search range
15   and the motion vectors (a motion vector 13 obtained by
scaling the motion vector candidate 11 and a motion
vector 17 obtained by scaling the motion vector
candidate 15 in FIG. 31) obtained by scaling the motion
vector candidates in accordance with the inter-frame
20   distance are used as motion vectors for the reference
frame F0. A predictive macroblock is generated from
the linear sum of the reference macroblocks 14 and 12
or 16 and 18 extracted from the two reference frames F0
and F1. The differential value between the predictive
25   macroblock and the to-be-encoded macroblock 10 is
calculated. When this differential value becomes
minimum, the corresponding motion vector is determined

as a motion vector search result for each macroblock.
Motion compensation predictive encoding is then
performed for each macroblock by using the determined
motion vector.

5   A motion vector may be determined in consideration
of the encoding overhead for each motion vector itself
as well as the above differential value. A motion
vector may be selected, which exhibits a minimum code
amount required to actually encode a differential
10   signal and the motion vector. As described above, the
motion vector search method can obtain an accurate
motion vector with a smaller computation amount than in
the method of separately searching for optimal motion
vectors for the reference frames F0 and F1.

15   FIG. 32 shows the second example of a motion
vector search in video encoding according to the
embodiment of the present invention. FIG. 32 shows a
motion vector search method in a case wherein a current
frame is predicted by using two consecutive frames as
20   reference frames, and one representative motion vector
is encoded or one representative motion vector and a
differential vector are encoded, as shown in FIG. 6, by
the same method as that shown in FIG. 31. Referring to
FIG. 32, reference symbol F2 denotes a video frame; and
25   F0 and F1, reference frames. Reference numeral 10
denotes a video macroblock; and 12, 14, 16, and 18,
reference macroblock candidates in the reference

frames.

In the second motion vector search, a search is made for one motion vector with respect to the two reference frames as in the first motion vector search. Referring to FIG. 32, a motion vector 11 and a motion vector 13 obtained by scaling the motion vector 11 are selected as optical motion vectors. A re-search is made for a motion vector with respect to a reference macroblock from the frame F0 in an area near the motion vector 13. In re-search operation, the reference frame 12 extracted from the frame F1 by using the motion vector 11 is fixed. A predictive macroblock is generated from the linear sum of the reference frame 12 and the reference frame 14 extracted an area near the motion vector 13 of the frame F0. A re-search is made for a motion vector with respect to the frame F0 so as to minimize the difference between the predictive macroblock and the to-be-encoded macroblock.

Assume that a video signal is set at a constant frame rate, and the interval between the frames F2 and F1 and the interval between the frames F1 and F0 are equal. In this case, in order to search for a constant movement, a search range with respect to the reference frame F0 needs to be four times larger in area ratio than a search range with respect to the reference frame F1. A search for a motion vector with respect to the two reference frames F0 and F1 with the same precision

requires a computation amount four times larger than that for a search for a motion vector in a prediction only from the reference frame F1.

According to the second motion vector search method, first of all, a search is made for a motion vector with respect to the reference frame F1 with full precision. The reference frame F0 is then searched for a motion vector obtained by scaling this motion vector twice. The reference frame F0 is re-searched with full precision. The use of such two-step search operation can reduce the computation amount for a motion vector search to almost 1/4.

In the second motion vector search method, motion vectors for the reference frames F0 and F1 are separately obtained. In encoding these motion vectors, first of all, the motion vector 11 for the reference frame F1 is encoded. The differential vector between the motion vector 13 obtained by scaling the motion vector 11 and the motion vector obtained as the result of re-searching the reference frame F0 is encoded. This makes it possible to reduce the encoding overhead for each motion vector.

A search is made for the motion vector 13 obtained scaling the motion vector 11 in a re-search range of ±1, i.e., with a coarse precision of 1/2. Only a re-search is made for the motion vector 13 with full precision. In this case, the motion vector with

respect to the re-searched reference frame F0 is scaled
to 1/2. This makes it possible to uniquely reconstruct
the motion vector 11 with respect to the reference
frame F1 regardless of the re-search result. There-

5   fore, only the motion vector with respect to the
reference frame F0 may be encoded. In a decoding
operation, the motion vector 11 with respect to the
reference frame F1 can be obtained by scaling the
received motion vector to 1/2.

10   FIG. 33 shows the third motion vector search
method. In this motion vector search method, a current
frame is predicted by using two consecutive frames as
reference frames, as in the method shown in FIG. 31, as
shown in FIG. 6. One representative motion vector is

15   encoded, or one representative motion vector and a
differential vector are encoded. Referring to FIG. 33,
reference symbol F2 denotes a video frame; and F0 and
F1, reference frames. Reference numeral 10 denotes a
video macroblock; and 12, 14, 16, and 18, some

20   reference macroblock candidates in the reference
frames.

In the third motion vector search, as in the first
or second example, searches are made for motion vectors
with respect to the reference frames F0 and F1, and a

25   re-search is made for a motion vector with respect to
the reference frame F1. In general, in a video
picture, the correlation between frames that are

temporally close to each other is strong. On the basis of this property, the prediction efficiency can be improved by obtaining a motion vector with respect to the reference frame F1 temporally closest to the reference frame F2 with higher precision in the third motion vector search.

FIG. 34 shows a motion vector encoding method according to the embodiment of the present invention. In figure, F2 shows a video frame, F1 shows a frame encoded immediately before the frame F2, 30 and 31 show macroblocks to be encoded respectively. 32 and 33 show macroblocks located at the same positions as those of the macroblocks 30 and 31 in the frame F1. 34 and 35 also show to-be-encoded motion vectors of the macroblocks 30 and 31, and 36 and 37 are encoded motion vectors of the macroblocks 32 and 33.

In this embodiment, if a to-be-encoded motion vector is identical to a motion vector for a macroblock at the same position in the immediately preceding video frame, the motion vector is not encoded, and a flag indicating that the motion vector is identical to that for the macroblock at the same position in the immediately preceding video frame is encoded as a prediction mode. If the motion vector is not identical to that for the macroblock at the same position in the immediately preceding video frame, the motion vector information is encoded. In the method shown in

FIG. 34, the motion vectors 34 and 36 are identical.
Therefore, the motion vector 34 is not encoded. In
addition, since the motion vector 35 differs from the
motion vector 37, the motion vector 35 is encoded.

Encoding motion vectors in the above manner
reduces the redundancy of motion vectors with respect
to a still picture or a picture which makes a
temporally uniform movement and hence can improve the
encoding efficiency.

FIG. 35 shows another motion vector encoding
method according to the embodiment of the present
invention. In the method shown in FIG. 35, as in the
method shown in FIG. 34, if a motion vector for a
macroblock at the same position in the immediately
preceding video frame is identical to a motion vector
for a video macroblock, the motion vector is not
encoded. Whether motion vectors are identical to each
other is determined depending on whether their moving
angles are identical. Referring to FIG. 35, a motion
compensation prediction is performed with respect to
macroblocks 40 and 41 in a video frame F3 by setting an
immediately preceding video frame F2 as a reference
frame and using motion vectors 44 and 45. With respect
to a macroblock 42 at the same position as that of the
macroblock 40 in the video frame F2 immediately
preceding a frame F1, a motion compensation prediction
is performed by setting a frame F0 two frames back with

respect to the frame F2 as a reference frame and using a motion vector 46.

Although the motion vectors 46 and 44 exhibit the same angle, the size of the motion vector 46 is twice that of the motion vector 44. Therefore, the motion vector 44 can be reconstructed by scaling the motion vector 46 in accordance with the inter-frame distance. For this reason, the motion vector 44 is not encoded, and prediction mode information indicating a mode of using a motion vector for the immediately preceding frame is set.

The motion vector 45 of the macroblock 41 exhibits the same angle as a motion vector 47 of the macroblock 43 at the same position in the preceding frame, and hence the motion vector 45 is not encoded as in the case of the macroblock 40. A macroblock for which a motion vector is not encoded as in the above case is subjected to motion compensation predictive inter-frame encoding and decoding by using the motion vector obtained by scaling the motion vector at the same position in the preceding video frame in accordance with the inter-frame distance between the video frame and the reference frame.

FIG. 36 is a view for explaining macroblock skipping and predictive encoding of an index indicating a reference frame according to the embodiment of the present invention. Referring to FIG. 36, reference

symbol F3 denotes a video frame; A, a video macroblock; B, C, D, and E, adjacent macroblocks that have already been encoded; and F0, F1, and F2, reference frames, one or a plurality of which are selected and subjected to motion compensation predictive encoding for each macroblock. With respect to the macroblock A, a prediction is performed based on a motion vector 50 by using the frame F1 as a reference frame. With respect to the macroblocks B, C, and E, predictions are performed based on motion vectors 51, 52, and 55 by using the frames F2, F1, and F0 as reference frames, respectively. The macroblock D is predicted by using the reference frames F1 and F2. When the motion vector 50 of the macroblock A is to be encoded, a prediction vector is selected from the motion vectors of the adjacent macroblocks B, C, D, and E, and the differential vector between the prediction vector and the motion vector 50 is encoded.

A prediction vector is determined by, for example, a method of selecting a motion vector corresponding to the median value of the motion vectors of the adjacent macroblocks B, C, and E or a method of selecting, as a prediction vector, the motion vector of one of the adjacent macroblocks B, C, D, and E which exhibits a minimum residual error signal.

Assume that the difference between the prediction vector and the motion vector of the to-be-encoded

macroblock becomes 0, the reference frame having the macroblock for which the prediction vector is selected coincides with the reference frame having the video macroblock to be encoded, and all the prediction error signals to be encoded become 0. In this case, the macroblock is skipped without being encoded. The number of macroblocks consecutively skipped is encoded as header information of a video macroblock to be encoded next without being skipped. Assume that a prediction vector for the macroblock A becomes the motion vector 52 of the macroblock C. In this case, the macroblock A coincides with the macroblock C in terms of reference frame, and the motion vector 50 coincides with the motion vector 52. If all the prediction error signals of the macroblock A are 0, the macroblock is skipped without being encoded. At the time of decoding, a prediction vector is selected by the same method as that used at the time of encoding, and a prediction picture is generated by using the reference frame of the macroblock for which the prediction vector is selected. The generated prediction picture is a decoded picture of the skipped macroblock.

If one of the above macroblock skipping conditions is not satisfied, the differential vector between the prediction vector and the motion vector of the video macroblock, the prediction error signal, and an index

indicating the reference frame are encoded.

As the index indicating the reference frame, the differential value between the reference frame index of an adjacent macroblock for which a prediction vector is selected and the reference frame index of the video frame is encoded.

When the motion vector 52 of the macroblock C is selected as the prediction vector of the macroblock A as in the above case, the differential vector between the motion vector 50 and the motion vector 52 and the prediction error signal of the macroblock A are encoded. Alternatively, for example, in accordance with the table shown in FIG. 23, a reference frame is expressed by an index (Code_number). A differential value between the index 2 indicating a reference frame for the macroblock C two frames back and the index 2 of the macroblock A, i.e., 0, is encoded as a reference frame index differential value.

FIG. 37 shows another motion vector encoding method according to the embodiment of the present invention. Referring to FIG. 37, a frame F2 is a video frame to be encoded, which is a B picture for which a motion compensation prediction is performed from temporally adjacent frames. With respect to a macroblock 61 in the frame F2, a frame F3 is used as a reference frame for a backward prediction, and a frame F1 is used as a reference frame for a forward

prediction. Therefore, the frame F3 is encoded or decoded before the frame F2 is encoded or decoded.

In the reference frame f3 for a backward prediction for the video macroblock 61, a macroblock 60 at the same position as that of the video macroblock 61 in the frame will be considered. If a motion compensation prediction based on the linear sum of the frames F0 and F1 is used, the motion vector (62 in the figure) of the macroblock 60 corresponding to the reference frame F1 for a forward prediction for the video macroblock 61 is scaled in accordance with the inter-frame distance, and the resultant vector is used as a vector for forward and backward predictions for the video macroblock 61.

Letting R1 be the inter-frame distance from the frame F1 to the frame F2, and R2 be the inter-frame distance from the frame F2 to the frame F3, the motion vector obtained by multiplying the motion vector 62 by $R1/(R1 + R2)$ becomes a motion vector 64 for a forward prediction for the macroblock 61. The motion vector obtained by multiplying the motion vector 62 by $-R2/(R1 + R2)$ becomes a motion vector 65 for a backward prediction for the macroblock 61.

With respect to the video macroblock 61, the above motion vector information is not encoded, and only a flag indicating the above prediction mode, i.e., the execution of a bi-directional prediction by motion

vector scaling, is encoded.

In a decoding operation, the frame F3 is decoded first. The motion vectors of the respective macroblocks of the decoded frame F3 are temporarily stored. In the frame F2, with respect to the macroblock for which the flag indicating the above prediction mode is set, motion vectors for forward and backward predictions at the macroblock 60 are calculated by scaling the motion vector of a macroblock at the same position in the frame F3, thereby performing bi-directional predictive decoding.

FIG. 38 shows another example of the bi-directional prediction shown in FIG. 37. Referring to FIG. 38, a frame F0 is a reference frame for a forward prediction for a video macroblock 71 of a video frame F2, and the other arrangements are the same as those in FIG. 37. In this case, forward and backward motion vectors for the video macroblock 71 are obtained by scaling a motion vector 73 of a macroblock 70 with respect to a frame F3, which is located at the same position as that of the video macroblock 71, to the frame F0 in accordance with the inter-frame distance. Letting R1 be the inter-frame distance from the frame F0 to the frame F2, R2 be the inter-frame distance from the frame F3 to the frame F2, and R3 be the inter-frame distance from the frame F0 to the frame F3, the vector obtained by multiplying the motion

vector 73 by R1/R3 is a forward motion vector 74 for the video macroblock 71. The vector obtained by multiplying the motion vector 73 by -R2/R3 is a backward motion vector 75 for the video macroblock 71.

5   Bi-directional predictive encoding and decoding of the video macroblock 71 are performed by using the motion vectors 74 and 75.

In the methods shown in FIGS. 37 and 38, in a reference frame for a backward prediction for a

10   bi-directional prediction video macroblock to be encoded, a macroblock at the same position as that of the video macroblock in the frame will be considered. When this macroblock uses a plurality of forward reference frames, forward and backward motion vectors

15   for the video macroblock are generated by scaling a motion vector with respect to the same reference frame as the forward reference frame for the bi-directional prediction video macroblock.

As described above, generation of motion vectors

20   by scaling in the above manner can reduce the encoding overhead for the motion vectors and improve the encoding efficiency. In addition, if there are a plurality of motion vectors on which scaling is based, the prediction efficiency can be improved by selecting

25   motion vectors exhibiting coincidence in terms of forward reference frame and scaling them. This makes it possible to realize high-efficiency encoding.

FIG. 39 shows another method for the
bi-directional predictions shown in FIGS. 37 and 38.
Referring to FIG. 39, a frame F3 is a video frame to be
encoded, and a video macroblock 81 to be encoded is
predicted by a bi-directional prediction using a frame
F4 as a backward reference frame and a frame F2 as a
forward reference frame. A macroblock 80 in the frame
F4 which is located at the same position as that of the
video macroblock 81 is predicted by the linear sum of
two forward frames F0 and F1. In the method shown in
FIG. 39, therefore, the same forward reference frame is
not used for the macroblock 80 and the video macroblock
81, unlike the methods shown in FIGS. 37 and 38.

In this case, a motion vector with respect to one
of the forward reference frames F0 and F1 for the
macroblock 80 which is temporally closer to the forward
reference frame F2 for the video macroblock 81 is
scaled in accordance with the inter-frame distance.
With this operation, forward and backward vectors for
the video macroblock 81 are generated. Letting R1 be
the inter-frame distance from the frame F2 to the frame
F3, R2 be the inter-frame distance from the frame F4 to
the frame F3, and R3 be the inter-frame distance from
the frame F1 to the frame F4, a forward motion vector
84 for the video macroblock 81 is obtained by
multiplying a motion vector 82 of the macroblock 80
with respect to the frame F1 by R1/R3. A backward

motion vector 85 for the to-be-encoded macroblock 81 is obtained by multiplying the motion vector 82 by -R2/R3. The video macroblock 81 is bi-directionally predicted by using the motion vectors 84 and 85 obtained by

5   scaling.

As described above, generation of motion vectors by scaling in the above manner can reduce the encoding overhead the motion vectors and improve the encoding efficiency. In addition, if there are a plurality of

10   motion vectors on which scaling is based, and there are no motion vectors exhibiting coincidence in terms of forward reference frame, a motion vector corresponding to a reference frame temporally closest to the forward reference frame for the video macroblock is selected

15   and scaled. This makes it possible to improve the prediction efficiency and realize high-efficiency encoding.

FIG. 40 is a flow chart of the video encoding method according to the embodiment of the present

20   invention. FIG. 41 is a view for explaining a weighting prediction according to the embodiment of the present invention. A weighting prediction according to the embodiment will be described with reference to FIG. 41. A weight factor determination method will

25   then be described with reference to FIG. 40.

Referring to FIG. 41, reference symbols F0, F1, F2, and F3 denote temporally consecutive frames. The

frame F3 is a video frame to be encoded. The frames
F0, F1, and F2 are reference frames for the video
frame F3.

Of to-be-encoded pixel blocks A, B, C, and D in
the video frame F3, for the blocks A, B, and C,
reference pixel block signals with motion compensation
are generated from the frames F1, F0, and F2, respec-
tively. With respect to these reference pixel block
signals, a prediction pixel block signal is generated
by multiplications of weight factors and addition of DC
offset values. The difference between the prediction
pixel block signal and the to-be-encoded pixel block
signal is calculated, and the differential signal is
encoded, together with the identification information
of the reference frames and motion vector information.

With respect to the block D, reference block
signals with motion compensation are respectively
generated from the frames F0 and F1. A prediction
pixel block signal is generated by adding a DC offset
value to the linear combination of the reference
pixel blocks. The difference signal between the
to-be-encoded pixel block signal and the prediction
pixel block signal is encoded, together with the
identification information of the reference frames and
motion vector information.

On the other hand, in a decoding operation, the
identification information of the reference frames and

motion vector information are decoded. The above reference pixel block signals are generated on the basis of these pieces of decoded information. A prediction pixel block signal is generated by performing multiplications of weight factors and addition of a DC offset value with respect to the generated reference pixel block signals. The encoded difference signal is decoded, and the decoded differential signal is added to the prediction pixel block signal to decode the video picture.

Prediction pixel block signals are generated in encoding and decoding operations by the following calculation. Letting predA be a prediction signal for the pixel block A, and ref[1] be a reference pixel block signal extracted from the frame F1, the signal predA is calculated as follows:

$$predA=w[1] \cdot ref[1]+d[1] \tag{42}$$

where w[1] is a weight factor for the reference pixel block, and d[1] is a DC offset value. These values are encoded as header data for each video frame or slice in a coefficient table. Weight factors and DC offset values are separately determined for a plurality of reference frames corresponding to each video frame. For example, with respect to the pixel block B in FIG. 41, since a reference pixel block ref[0] is extracted from the frame F0, a prediction signal predB is given by the following equation:

$$predB = w[0] \bullet red[0] + d[0] \tag{43}$$

With respect to the pixel block D, reference pixel blocks are extracted from the frames F0 and F1, respectively. These reference pixel blocks are multiplied by weight factors, and DC offset values are added to the products. The resultant signals are then averaged to generate a prediction signal predD

$$predD = \{w[0] \bullet ref[0] + w[1] \bullet ref[1] + (d[0] + d[1])\} / 2 \tag{44}$$

In this embodiment, a weight factor and DC offset value are determined for each reference frame in this manner.

A method of determining the above weight factors and DC offset values in an encoding operation according to this embodiment will be described with reference to FIG. 40. The method of determining weight factors and DC offset values will be described with reference to the flow chart of FIG. 40, assuming that the inter-frame prediction relationship shown in FIG. 41 is maintained, i.e., the frame F3 is a video frame, and the frames F0, F1, and F2 are reference frames.

Weight factors and DC offset values are regarded as independent values with respect to a plurality of reference frames, and weight factor/DC offset data table data is encoded for each video frame or slice. For example, with respect to the video frame F3 in FIG. 41, weight factors and DC offset values (w[0], d[0]), (w[1], d[1]), and (w[2], d[2]) corresponding to

the frames F0, F1, and F2 are encoded. These values may be changed for each slice in the video frame.

First of all, an average value DCcur (a DC component intensity to be referred to as a DC component value hereinafter) of pixel values in the entire to-be-encoded frame F3 or in each slice in the frame is calculated as follows (step S10).

$$DCcur = \frac{\sum\limits_{x,y} F3(x,\ y)}{N} \tag{45}$$

where F3(x, y) is a pixel value at a coordinate position (x, y) in the frame F3, and N is the number of pixels in the frame or a slice. The AC component intensity (to be referred to as an AC component value hereinafter) of the entire video frame F3 or each slice in the frame is then calculated by the following equation (step S11):

$$ACcur = \frac{\sum\limits_{x,y} |F3(x,y) - DCcur|}{N} \tag{46}$$

In measurement of an AC component value, a standard deviation like the one described below may be used. In this case, the computation amount in obtaining an AC component value increases.

$$ACcur = \sqrt{\frac{\sum\limits_{x,y} (F3(x,y) - DCcur)^2}{N}} \tag{47}$$

As is obvious from a comparison between equations

(46) and (47), the AC component value measuring method based on equation (46) is effective in reducing the computation amount in obtaining an AC component value.

Letting "ref_idx" be an index indicating a
reference frame number, a DC component value DCref[ref_idx] of the (ref_idx)-th reference frame and an AC component value ACref[rf_idx] are calculated according to equations (45) and (46) (steps S13 and S14).

On the basis of the above calculation result, a DC offset value d[ref_idx] with respect to the (ref_idx)-th reference frame is determined as the difference between DC components as follows (step S15):

$$d[ref\_idx] = DCcur - DCref[ref\_idx] \qquad (48)$$

A weight factor w[ref_idx] is determined as an AC gain (step S16).

$$w[ref\_idx] = ACcur / ACref[ref\_idx] \qquad (49)$$

The above calculation is performed with respect to all the reference frames (from ref_idx = 0 to MAX_REF_IDX) (steps S17 and S18). MAX_REF_IDX indicates the number of reference frames. When all weight factors and DC offset values are determined, they are encoded as table data for each video frame or slice, and weighted predictive encoding of the respec-tive pixel blocks is performed in accordance with the encoded weight factors and DC offset values. Prediction pixel block signals in encoding and decoding

operations are generated according to equations (42) to (44) described above.

As described above, generation of prediction signals by using weight factors and DC offset values which vary for each reference frame and performing predictive encoding in the above manner can properly generate prediction signals from a plurality of reference frames and realize high-prediction-efficiency encoding with higher efficiency and high picture quality even with respect to a video signal which varies in signal amplitude for each frame or slice over time or varies in DC offset value.

A specific example of the method of encoding information of weight factors and DC offset values will be described next. FIGS. 42, 43 and 44 show data structures associated with encoding of information of weight factors and DC offset values.

FIG. 42 shows part of the header data structure of a video frame to be encoded or slice. A maximum index count "number_of_max_ref_idx" indicating reference frames for the video frame or slice and a table data "weighting_table()" indicating information of weight factors and DC offset values are encoded. The maximum index count "number_of_max_ref_idx" is equivalent to MAX_REF_IDX in FIG. 40.

FIG. 43 shows the first example of an encoded data structure concerning the weight factor/DC offset data

table. In this case, the data of weight factors and DC offset values corresponding to each reference frame are encoded in accordance with the maximum index count "number_of_max_ref_idx" sent as the header data of the frame or slice. A DC offset value d[i] associated with the ith reference frame is directly encoded as an integral pixel value.

On the other hand, a weight factor w[i] associated with the ith reference frame is not generally encoded into an integer. For this reason, as indicated by equation (50), the weight factor w[i] is approximated with a rational number w'[i] whose denominator becomes a power of 2 so as to be encoded into a numerator [i] expressed in the form of an integer and a denominator to the power of 2 w_exponential_denominator.

$$w'[i] = \frac{w\_numerator[i]}{2^{w\_exponential\_denominator}} \qquad (50)$$

The value of the numerator and the denominator to the power of 2 can be obtained by the following equation (51):

$$w\_numerator[i] = (int)w[i] \times 2^{w\_exponential\_denominator}$$

$$w\_exponential\_denominator = (int)\log_2\left(\frac{255}{\max_i(w[i])}\right)$$

$$(51)$$

In encoding and decoding operations, a prediction picture is generated by using the above encoded approximate value w'[i]. According to equations (50) and (51), the following merits can be obtained.

According to the weight factor expression based on equation (50), the denominator of the weight factor is constant for each video frame, whereas the numerator changes for each reference frame. This encoding method

5　　　can reduce the data amount of weight factors to be encoded, decrease the encoding overhead, and improve the encoding efficiency as compared with the method of independently encoding weight factors for each reference frame into denominators and numerators.

10　　　If the denominator is set to a power of 2, since multiplications of weight factors with respect to reference pixel block signals can be realized by multiplications of integers and bit shifts, no floating-point operation or division is required. This

15　　　makes it possible to reduce the hardware size and computation amount for encoding and decoding.

The above computations will be described in further detail below. Equation (52) represents a prediction expression obtained by generalizing the

20　　　predictive expression indicated by equations (42) and (43) and is used for the generation of a prediction pixel block signal for a pixel block corresponding to a reference frame number i. Let $Pred_i$ be a prediction signal, ref[i] be the reference pixel block signal

25　　　extracted from the ith reference frame, and w[i] and d[i] are a weight factor and DC offset value for the reference pixel block extracted from the ith reference

frame.

$$Pred_i = w[i] \cdot ref[i] + d[i] \qquad (52)$$

Equation (53) is a prediction expression in a case wherein the weight factor w[i] in equation (52) is expressed by the rational number indicated by equation (50). In this case, wn[i] represents w_numerator[i] in equation (50), and wed represents w_exponential_denominator.

$$Pred_i = ((wn[i] \cdot ref[i] + 1 << (wed - 1)) >> wed) + d[i]$$
$$(53)$$

In general, since the weight factor w[i] which is effective for an arbitrary fading picture or the like is not an integer, a floating-point multiplication is required in the equation (52). In addition, if w[i] is expressed by an arbitrary rational number, an integer multiplication and division are required. If the denominator indicated by equation (50) is expressed by a rational number which is a power of 2, a weighted predictive computation can be done by an integer multiplication using an integral coefficient wn[i], adding of an offset in consideration of rounding off, a right bit shift of wed bit, and integral addition of a DC offset value, as indicated by equation (53). This eliminates the necessity for floating-point multiplication.

Also, a power of 2 which indicates the magnitude of a denominator is commonly set for each video frame

or slice regardless of a reference frame number i.
Even if, therefore, the reference frame number i takes
a plurality of values for each video frame, an increase
in code amount in encoding weight factors can be

5   suppressed.

Equation (54) indicates a case wherein the weight
factor representation based on equation (50) is applied
to a prediction based on the linear sum of two
reference frames indicated by equation (44), as in the

10 case with equation (53).

$$Pred = \left((wn[0] * ref[0] + wn[1] \bullet ref[1] + 1 << wed) >> (wed + 1)\right) + \left(d[0] + d[1] + 1\right) >> 1$$

(54)

In the above prediction based on the linear sum

15 of two reference frames as well, since a weight factor
is not generally encoded into an integer, two
floating-point multiplications are required according
to equation (44). According to equation (54), however,
a prediction signal can be generated by the linear sum

20 of two reference frames by performing only an integer
multiplication, bit shift, and integer addition. In
addition, since information wed concerning the
magnitude of a denominator is also commonized, an
increase in code amount in encoding a weight factor can

25 be suppressed.

Also, according to equation (54), the numerator of
a weight factor is expressed by eight bits. If,
therefore, a pixel signal value is expressed by eight

bits, encoding and decoding can be done with a constant computation precision of 16 bits.

In addition, within the same video frame, a denominator, i.e., a shift amount, is constant regardless of reference frames. In encoding or decoding, therefore, even if reference frames are switched for each pixel block, there is no need to change the shift amount, thereby reducing the computation amount or hardware size.

If weight factors for all reference frames satisfy

$$w\_numerator[i] = 2^n \times K_i \qquad (55)$$

the denominator and numerator of the to-be-encoded weight factor to be calculated by equation (54) may be transformed as follows:

$$w\_numerator[i] = w\_numerator[i] >> n$$
$$w\_exponential\_denominator$$
$$= w\_exponential\_denominator - n$$
$$(56)$$

Equation (56) has the function of reducing each weight factor expressed by a rational number to an irreducible fraction. Encoding after such transformation can reduce the dynamic range of the encoded data of weight factors without decreasing the weight factor precision and can further reduce the code amount in encoding weight factors.

FIG. 44 shows the second example of the video data structure associated with a weight factor/DC offset data table. In the case shown in FIG. 44 a DC offset value is encoded in the same manner as in the form

shown in FIG. 43. In encoding a weight factor, however, a power of 2 which indicates a denominator is not encoded unlike in the form shown in FIG. 43, and only the numerator of weight factor which is expressed by a rational number is encoded while the denominator is set as a constant value. In the form shown in FIG. 44, for example, a weight factor may be expressed by a rational number, and only a numerator w_numerator[i] may be encoded as follows.

$$w'[i] = \frac{w\_numerator[i]}{2^4} \qquad (57)$$

$$w\_numerator[i] = \begin{cases} 1 & , if\ w[i] \le \frac{1}{16} \\ 255 & , if\ w[i] \ge 16 \\ (int)w[i] \times 2^4 & , else \end{cases}$$
$$w\_exponential\_denominator = 4$$

$$(58)$$

In this embodiment, since the power of 2 which represents the denominator of the weight factor is constant, there is no need to encode information concerning the denominator to the power of 2 for each video frame, thereby further reducing the code amount in encoding a weight factor table.

Assume that in making a rational number representation with a constant numerator ("16" in the above case), the value of the numerator is clipped to eight bits. In this case, if, for example, a pixel signal is expressed by eight bits, encoding and decoding can be done with a constant computation

precision of 16 bits.

In addition, in this embodiment, since the shift amount concerning a multiplication of a weight factor is constant, there is no need to load a shift amount

5   for each frame in encoding and decoding. This makes it possible to reduce the implementation cost of an encoding or decoding apparatus or software or hardware size.

FIG. 45 schematically shows the overall

10   time-series structure of to-be-encoded video data including the data structures shown in FIGS. 42 to 44. In the head of the video data to be encoded, information of a plurality of encoding parameters which remain constant within one encoding sequence, such as a

15   picture size, is encoded as a sequence header (SH). Each picture frame or field is encoded as a picture, and each picture is sequentially encoded as a combination of a picture header (PH) and picture data (Picture data).

20   In the picture header (PH), a maximum index count "number_of_max_ref_idx" indicating reference frames and a weight factor/DC offset data table "weighting_table()", which are shown in FIG. 42, are encoded as MRI and WT, respectively. In

25   "weighting_table()"(WT), a power of 2 w_exponential_denominator indicating the magnitude of the denominator common to the respective weight factors

as shown in FIG. 43 is encoded as WED, and

w_numerator[i] indicating the magnitude of the

numerator of each weight factor and a DC offset value

d[i] are encoded WN and D, respectively, following

5   w_exponential_denominator.

With regard to combinations of weight factor

numerators and DC offset values, a plurality

combinations of WNs and Ds are encoded on the basis of

the number indicated by "number_of_max_ref_idx"

10   contained in the picture header. Each picture data is

divided into one or a plurality of slices (SLCs), and

the data are sequentially encoded for each slice. In

each slice, an encoding parameter associated with each

pixel block in the slice is encoded as a slice header

15   (SH), and one or a plurality of macroblock data (MB)

are sequentially encoded following the slice header.

With regard to macroblock data, information

concerning encoding of each pixel in the macroblock,

e.g., prediction mode information (MBT) of a pixel

20   block in the macroblock and motion vector information

(MV), is encoded. Lastly, the encoded orthogonal

transform coefficient (DCT) obtained by computing the

orthogonal transform (e.g., a discrete cosine

transform) of the to-be-encoded pixel signal or

25   prediction error signal is contained in the macroblock

data. In this case, both or one of

""number_of_max_ref_idx" and "weighting_table()"(WT)

contained in the picture header may be encoded within the slice header (SH).

In the arrangement of the weight factor table data shown in FIG. 44, since encoding of data indicating the magnitude of the denominator of a weight factor can be omitted, encoding of WED in FIG. 45 can be omitted.

FIG. 46 is a flow chart showing a video decoding procedure according to the embodiment of the present invention. A procedure for inputting the encoded data, which is encoded by the video encoding apparatus according to the embodiment described with reference to FIG. 40, and decoding the data will be described below.

The header data of an encoded frame or slice, which includes the weight factor/DC offset data table described with reference to FIGS. 42 to 44, is decoded from the input encoded data (step S30). The header data of an encoded block, which includes a reference frame index for identifying a reference frame for each encoded block, is decoded (step S31).

A reference pixel block signal is extracted from the reference frame indicated by the reference frame index for each pixel block (step S32). A weight factor and DC offset value are determined by referring to the decoded weight factor/DC offset data table on the basis of the reference frame index of the encoded block.

A prediction pixel block signal is generated from the reference pixel block signal by using the weight

factor and DC offset value determined in this manner
(step S33). The encoded prediction error signal is
decoded, and the decoded prediction error signal is
added to the prediction pixel block signal to generate
5   a decoded picture (step S34).

When the respective encoded pixel blocks are
sequentially decoded and all the pixel blocks in the
encoded frame or slice are decoded, the next picture
header or slide header is continuously decoded.

10   The encoding and decoding methods following the
above procedures can generate proper prediction
pictures in encoding and decoding operations even with
respect to a vide signal which varies in signal
amplitude over time or varies in DC offset value
15   over time, thereby realizing high-efficiency,
high-picture-quality video encoding and decoding with
higher prediction efficiency.

The preferable forms of the present invention
disclosed in the above embodiments will be described
20   below one by one.

(1) In a video encoding method of performing
motion compensation predictive inter-frame encoding of
a to-be-encoded macroblock of a video picture by using
a predetermined combination of a plurality of reference
25   frames and a motion vector between the to-be-encoded
macroblock and at least one reference frame, (a) at
least one reference macroblock is extracted from each

of the plurality of reference frames, (b) a predictive

macroblock is generated by calculating the linear sum

of the plurality of extracted reference macroblocks by

using a predetermined combination of weighting factors,

and (c) a predictive error signal between the

predictive macroblock and the to-be-encoded macroblock

is generated to encode the predictive error signal, the

first index indicating the combination of the plurality

of reference frames, the second index indicating the

combination of the weighting factors, and the

information of the motion vector.

<Effects>

Performing a prediction based on the linear sum of

a plurality of reference frames with variable linear

sum weighting factors in this manner allows a proper

prediction with respect to changes in signal intensity

over time such as fading. This makes it possible to

improve the prediction efficiency in encoding. In

addition, for example, in a portion where occlusion

(appearing and disappearing) temporally occurs, the

prediction efficiency can be improved by selecting

proper reference frames. Encoding these combinations

of these linear predictive coefficients and reference

frames as indexes can suppress the overhead.

(2) In (1), an index indicating the combination

of linear sum weighting factors is encoded as header

data for each frame or each set of frames, and the

predictive error signal, the index indicating the combination of reference frames, and the motion vector are encoded for each macroblock.

<Effects>

In general, changes in signal intensity over time such as fading occur throughout an entire frame, and occlusion or the like occurs locally in the frame. According to (2), one combination of linear predictive coefficients made to correspond to a change in signal intensity over time is encoded for each frame, and an index indicating a combination of reference frames is made variable for each macroblock. This makes it possible to improve the encoding efficiency while reducing the encoding overhead, thus achieving an improvement in encoding efficiency including overhead.

(3)   In (1) or (2), the motion vector to be encoded is a motion vector associated with a specific one of the plurality of reference frames.

<Effects>

In performing motion compensation predictive encoding using a plurality of reference frames for each macroblock, when a motion vector for each macroblock is individually encoded, the encoding overhead increases. According to (3), a motion vector for a specific reference frame is transmitted, and motion vectors for other frames are obtained by scaling the transmitted motion vector in accordance with the inter-frame

distances between the to-be-encoded frame and the respective reference frames. This makes it possible prevent an increase in encoding overhead and improve the encoding efficiency.

5   (4) In (3), the motion vector associated with the specific reference frame is a motion vector that is normalized in accordance with the reference frame and the to-be-encoded frame.

<Effects>

10   Since the motion vector normalized with the unit inter-frame distance is used as a motion vector to be encoded in this manner, motion vector scaling with respect to an arbitrary reference frame can be performed at low cost by multiplication or shift

15   computation and addition processing. Assuming temporally uniform movement, normalization with a unit inter-frame distance minimizes the size of a motion vector to be encoded and can reduce the information amount of the motion vector, thus obtaining the effect

20   of reducing the encoding overhead.

     (5) In (3), the motion vector associated with the specific reference frame is a motion vector for one of the plurality of reference frames which corresponds to the greatest inter-frame distance from the

25   to-be-encoded frame.

<Effects>

     According to (3), the motion vector code amount

decreases and scaling of a motion vector can be realized at a low cost. On the other hand, as the inter-frame distance between a reference frame and a to-be-encoded frame increases, the precision of motion compensation decreases. In contrast to this, according to (5), a motion vector for one of a plurality of reference frames which corresponds to the greatest inter-frame distance is encoded, and motion vectors for the remaining reference frames can be generated by interior division of the encoded motion vector in accordance with the inter-frame distances. This can suppress a decrease in motion compensation precision with respect to each reference frame. This makes it possible to improve the prediction efficiency and perform high-efficiency encoding.

(6) In (1) or (2), the motion vectors to be encoded are the first motion vector associated with one specific reference frame of the plurality of reference frames and a motion vector for another or other reference frames, and the motion vector for another or other reference frames is encoded as a differential vector between another or other motion vectors and the motion vector obtained by scaling the first motion vector in accordance with the inter-frame distance between the to-be-encoded frame and one or the plurality of reference frames.

<Effects>

If a local temporal change in picture can be approximated by translation, a prediction can be made from a plurality of reference frames using one motion vector and the motion vectors obtained by scaling it in accordance with the inter-frame distances. If, however, the speed of a change in picture is not temporally constant, it is difficult to perform proper motion compensation by scaling alone. According to (6), as motion vectors for a plurality of reference frames, one representative vector and a differential vector between the motion vector obtained by scaling the representative vector and an optimal motion vector for each reference frame are encoded. This makes it possible to reduce the code amount of motion vectors as compared with the case wherein a plurality of motion vectors are encoded. This therefore can reduce the encoding overhead while improving the prediction efficiency.

(7) In (6), the first motion vector is a motion vector normalized in accordance with the inter-frame distance between the reference frame and the frame to be encoded.

(8) In (6), the first motion vector is a motion vector for one of the plurality of reference frames which corresponds to the greatest inter-frame distance from the frame to be encoded.

(9)   In any one of (1) to (8), encoding is skipped without outputting any encoded data with respect to a macroblock when an index indicating a combination of the plurality of reference frames is a predetermined value, all the elements of the motion vector to be encoded are 0, and all the predictive error signals to be encoded are 0.   With regard to the macroblock to be encoded next, the number of skipped macroblocks is encoded.

<Effects>

If the above conditions are made to coincide with each other on the transmission side and reception side as conditions for skipping macroblocks, a picture can be played back on the reception side without sending an index indicating a combination of reference frames, a motion vector with a size of 0, and a 0 error signal, which are encoding information for each macroblock, upon encoding them.   This makes it possible to reduce the encoded data amount corresponding to these data and improve the encoding efficiency.   In addition, encoding a predictive coefficient corresponding to a temporal change in signal intensity for each frame can realize adaptive macroblock skipping in accordance with the characteristics of a picture signal without increasing the encoding overhead.

(10)   In any one of (1) to (8), encoding is skipped without outputting any encoded data with

respect to a macroblock when an index indicating a combination of the plurality of reference frames is a predetermined value, the motion vector to be encoded coincides with a motion vector for the immediately previously encoded macroblock, and all the predictive error signals to be encoded are 0. With regard to the macroblock to be encoded next, the number of skipped macroblocks is encoded.

<Effects>

When, for example, an area larger than a macroblock in a frame temporally translates, the corresponding macroblock can be encoded as a skip macroblock without sending any motion vector information. This makes it possible to reduce the encoding overhead and improve the encoding efficiency.

(11) In (9) or (10), an index indicating the predetermined combination of reference frames indicates the use of two immediately previously encoded frames as reference frames.

<Effects>

When the use of two immediately previously encoded frames as reference pictures is set as a macroblock skipping condition, an accurate predictive picture can be easily generated by a linear prediction such as linear extrapolation even in a case wherein a signal intensity changes over time due to fading or the like. In spite of the fact that the signal intensity changes

over time, encoding of a macroblock can be skipped.
The two effects, i.e., an improvement in prediction
efficiency and a reduction in encoding overhead, make
it possible to improve the encoding efficiency.

5   (12) In (9) or (10), an index indicating the
predetermined combination of reference frames can be
changed for each to-be-encoded frame, and the index
indicating the predetermined combination of reference
frames is encoded as header data for a to-be-encoded

10   frame.

<Effects>

The macroblock skipping conditions can be flexibly
changed in accordance with a change in picture signal
over time. By properly changing the skipping

15   conditions for each frame in accordance with a picture
so as to easily cause macroblock skipping at the time
of encoding, the encoding overhead can be reduced, and
high-efficiency encoding can be realized.

(13) In any one of (1) to (8), encoding is

20   skipped without outputting any encoded data with
respect to a macroblock when an index indicating a
combination of the plurality of reference frames is the
same as that for the immediately previously encoded
macroblock, all the elements of the motion vector to be

25   encoded are 0, and all the predictive error signals to
be encoded are 0. With regard to the macroblock to be
encoded next, the number of skipped macroblocks is

encoded.

<Effects>

When the use of the same combination of reference frames as that for the immediately preceding macroblock is set as a macroblock skipping condition, macroblock skipping can be efficiently done by utilizing the spatiotemporal characteristic correlation between areas adjacent to a video signal. This can improve the encoding efficiency.

(14) In any one of (1) to (8), encoding is skipped without outputting any encoded data with respect to a macroblock when an index indicating a combination of the plurality of reference frames is the same as that for the immediately previously encoded macroblock, the motion vector to be encoded coincides with a motion vector for the immediately previously encoded macroblock, and all the predictive error signals to be encoded are 0. With regard to the macroblock to be encoded next, the number of skipped macroblocks is encoded.

<Effects>

Adding the arrangement in (14) to that in (13) makes it possible to reduce the encoding overhead and improve the encoding efficiency.

(15) In any one of (1) to (8), the motion vector to be encoded is predicted from a motion vector for one or a plurality of adjacent macroblocks within the

frame, and the differential vector between the motion vector to be encoded and the predicted motion vector is encoded.

<Effects>

The encoding overhead for motion vectors can be reduced and the encoding efficiency can be improved more than in (1) to (8) by predicting a motion vector to be encoded from adjacent macroblocks within the frame in consideration of the spatial correlation between motion vectors, and encoding only the differential vector.

(16) In any one of (1) to (8), the motion vector to be encoded is predicted from a motion vector for a macroblock at the same position in the immediately previously encoded frame, and the differential vector between the motion vector to be encoded and the predicted motion vector is encoded.

<Effects>

The encoding overhead for motion vectors can be reduced and the encoding efficiency can be further improved by predicting a motion vector to be encoded from a motion vector for a macroblock at the same position in the immediately previously encoded frame in consideration of the temporal correlation between motion vectors, and encoding only the differential vector.

(17) In any one of (1) to (8), the motion vector

to be encoded is predicted from a motion vector for one
or a plurality of macroblocks within the frame and a
motion vector for a macroblock at the same position in
the immediately previously encoded frame, and the
differential vector between the motion vector to be
encoded and the predicted motion vector is encoded.
<Effects>

Both the characteristics in (15) and (16) can
be obtained by predicting a motion vector within a
frame and between frames in consideration of the
spatiotemporal characteristic correlation between
motion vectors. This makes it possible to further
improve the encoding efficiency for motion vectors.

(18) In ay one of (15) to (17), encoding is
skipped without outputting any encoded data with
respect to a macroblock when an index indicating a
combination of the plurality of reference frames is a
predetermined value, the differential vector of the
motion vector to be encoded is 0, and all the
predictive error signals to be encoded are 0. With
regard to the macroblock to be encoded next, the number
of skipped macroblocks is encoded.
<Effects>

In synergy with the arrangement of any one of (15)
to (17), the encoding overhead can be further reduced
to improve the encoding efficiency.

(19) In any one of (15) to (17), encoding is

skipped without outputting any encoded data with respect to a macroblock when an index indicating a combination of the plurality of reference frames is a predetermined value, the differential vector of the motion vector to be encoded coincides with a differential vector for the immediately previously encoded macroblock, and all the predictive error signals to be encoded are 0. With regard to the macroblock to be encoded next, the number of skipped macroblocks is encoded.

<Effects>

In synergism with the arrangement of any one of (15) to (17) and the arrangement of (10), the encoding overhead can be further reduced to improve the encoding efficiency.

(20) In (18) or (19), an index indicating the predetermined combination of reference frames indicates the use of two immediately previously encoded frames as reference frames.

<Effects>

In synergism with the arrangement of (18) or (19) and the arrangement of (11), the encoding overhead can be further reduced to improve the encoding efficiency.

(21) In (18) or (19), an index indicating the predetermined combination of reference frames can be changed for each to-be-encoded frame, and the index indicating the predetermined combination of reference

frames is encoded as header data for a to-be-encoded frame.

<Effects>

In synergism with the arrangement of (18) or (19) and the arrangement of (12), the encoding overhead can be further reduced to improve the encoding efficiency.

(22) In any one of (15) to (17), encoding is skipped without outputting any encoded data with respect to a macroblock when an index indicating a combination of the plurality of reference frames is the same as that for the immediately previously encoded macroblock, all the elements of the differential vector of the motion vector to be encoded are 0, and all the predictive error signals to be encoded are 0. With regard to the macroblock to be encoded next, the number of skipped macroblocks is encoded.

<Effects>

In synergism with the arrangement of any one of (15) to (17) and the arrangement of (13), the encoding overhead can be reduced to improve the encoding efficiency.

(23) In any one of (15) to (17), encoding is skipped without outputting any encoded data with respect to a macroblock when an index indicating a combination of the plurality of reference frames is the same as that for the immediately previously encoded macroblock, the differential vector of the motion

vector to be encoded coincides with a differential vector for the immediately previously encoded macroblock, and all the predictive error signals to be encoded are 0. With regard to the macroblock to be encoded next, the number of skipped macroblocks is encoded.

<Effects>

In synergism with the arrangement of any one of (15) to (17) and the arrangement of (14), the encoding overhead can be reduced to improve the encoding efficiency.

(24) In (1) or (2), the combination of linear sum weighting factors is determined in accordance with the inter-frame distances between a to-be-encoded frame and a plurality of reference frames.

<Effects>

A proper predictive picture can be easily generated at a low cost by performing linear interpolation or linear extrapolation for a time jitter in signal intensity such as fading in accordance with the inter-frame distances between a to-be-encoded frame and a plurality of reference frames. This makes it possible to realize high-efficiency encoding with high prediction efficiency.

(25) In (1) or (2), an average DC value in a frame or field in an input video signal is calculated, and the combination of linear sum weighting factors is

determined on the basis of the DC values in a plurality

of reference frames and a to-be-encoded frame.

<Effects>

By calculating linear predictive coefficients from

5   temporal changes in DC value in a to-be-encoded frame

and a plurality of reference frames, a proper

predictive picture can be generated with respect to not

only a constant temporal change in signal intensity but

also an arbitrary time jitter in signal intensity.

10   (26) In (1) or (2), assume that an input video

signal has a variable frame rate or an encoder for

thinning out arbitrary frames of the input video signal

to make it have a variable frame rate is prepared. In

this case, in encoding the video signal having the

15   variable frame rate, the combination of linear sum

weighting factors is determined in accordance with

changes in inter-frame distance between a to-be-encoded

frame and a plurality of reference frames.

<Effects>

20   By using proper linear predictive coefficients in

accordance with inter-frame distances with respect to

encoding with a variable frame rate in which the

inter-frame distances between a to-be-encoded frame and

a plurality of reference frames dynamically change,

25   high prediction efficiency can be maintained to perform

high-efficiency encoding.

(27) In a video encoding method of performing

motion compensation predictive inter-frame encoding of a to-be-encoded macroblock of a video picture by using a predetermined combination of a plurality of reference frames and a motion vector between the to-be-encoded

5   macroblock and at least one reference frame, (a) the first reference macroblock corresponding to a candidate for the motion vector is extracted from the first reference frame, (b) the candidate for the motion vector is scaled in accordance with the inter-frame

10   distance between at least one second reference frame and the to-be-encoded frame, (c) at least one second reference macroblock corresponding to the candidate for the motion vector obtained by scaling is extracted from the second reference frame, (d) a predictive macroblock

15   is generated by calculating a linear sum using a predetermined combination of weighting factors for the first and second reference macroblocks, (e) a predictive error signal between the predictive macroblock and the to-be-encoded macroblock is

20   generated, (f) the motion vector is determined on the basis of the magnitude of the predictive error signal between the linear sum of the first and second reference macroblocks and the to-be-encoded macroblock, and (g) the predictive error signal, the first index

25   indicating the first and second reference frames, the second index indicating the combination of weighting factors, and the information of the determined motion

vector are encoded.

<Effects>

Assume that a plurality of reference macroblocks are extracted from a plurality of reference frames with respect to one to-be-encoded macroblock, and a predictive macroblock is generated from the linear sum. In this case, if an optimal motion vector is determined for each reference frame, the computation amount becomes enormous. According to the arrangement of (27), since a motion vector candidate for the first reference frame is scaled to obtain motion vectors for other reference frames, a plurality of optimal motion vectors can be searched out with a very small computation amount. This makes it possible to greatly reduce the encoding cost.

(28) In (27), the determined motion vector is scaled in accordance with the distances between the respective reference frames and the to-be-encoded frame, and a reference macroblock for at least one reference frame is individually searched again so as to reduce the propriety error signal near the scaled motion vector. A motion compensation prediction is then performed by using the motion vector obtained as a result of the re-search.

<Effects>

Making a re-search for a motion vector near the scaled motion vector candidate can realize a

higher-efficiency motion vector search with a smaller
computation amount and realize a high-efficiency motion
compensation prediction with a slight increase in
computation amount. This makes it possible to perform

5   high-efficiency encoding.

(29)   In a video encoding method of performing
motion compensation inter-frame encoding of a
to-be-encoded macroblock of a video picture by using at
least one past reference frame and a motion vector

10   between the to-be-encoded macroblock and the reference
frame, the motion compensation predictive inter-frame
encoding is performed upon switching, for each
to-be-encoded macroblock, between operation of using a
motion vector for a to-be-decoded macroblock at the

15   same intra-frame position as that of the to-be-encoded
macroblock in the frame encoded immediately before the
to-be-encoded frame containing the to-be-encoded
macroblock and operation of newly determining and
encoding the motion vector.

20   <Effects>

As has been described above, in motion
compensation predictive encoding, the overhead for
motion vector encoding influences the encoding
efficiency. When, in particular, a picture with high

25   prediction efficiency is to be encoded or many motion
vectors are to be encoded because of a small macroblock
size, the code amount of motion vector may become

dominant. According to the arrangement of (29), the
temporal correlation between the movements of pictures
is used such that a motion vector for a macroblock at
the same position as that of a to-be-encoded macroblock

5   in the immediately preceding frame is not encoded if
the macroblock can be used without any change, and a
motion vector for only a macroblock which is subjected
to a decrease in prediction efficiency when the motion
vector for the immediately preceding frame is used is

10   encoded. This makes it possible to reduce the overhead
for motion vector encoding and realize high-efficiency
encoding.

(30)   In a video encoding method of performing
motion compensation predictive inter-frame encoding of

15   a to-be-encoded macroblock of a video picture by using
at least one reference frame and a motion vector
between the to-be-encoded macroblock and the reference
frame, the motion compensation predictive inter-frame
encoding is performed upon switching, for each

20   to-be-encoded macroblock, between (a) the first
prediction mode of using at least one encoded past
frame as the reference frame, (b) the second prediction
mode of using an encoded future frame as the reference
frame, (c) the third prediction mode of using the

25   linear sum of the encoded past and future frames as the
reference frame, and (d) the fourth prediction mode of
using the linear sum of the plurality of encoded past

reference frames as the reference frame.

<Effects>

In the case of B pictures (bi-directional predictive encoding) used for MPEG2 video encoding, a prediction from one forward frame, a prediction from one backward frame, and an average prediction from forward and backward frames are switched for each macroblock. In the average prediction, averaging processing functions as a loop filter to remove original image noise or encoding noise in a reference frame, thereby improving the prediction efficiency. Note, however, that a bi-directional prediction is difficult to make before and after a scene change, and hence a prediction is made from one forward or backward frame. In this case, no loop filter effect works, and the prediction efficiency decreases. According to the arrangement of (30), even in a prediction from only a forward frame, since a predictive picture is generated from the linear sum of a plurality of reference frames, the prediction efficiency can be improved by the loop filter effect.

(31) In (30), the prediction based on the linear sum includes linear interpolation and linear extrapolation corresponding to inter-frame distances.

<Effects>

Even if the signal intensity changes over time due to fading or the like, a proper predictive picture can

be easily generated by linear interpolation or linear extrapolation from a plurality of frames. This makes it possible to obtain high prediction efficiency.

(32) In a video decoding method of performing motion compensation predictive inter-frame decoding of a to-be-decoded macroblock of a video picture by using a predetermined combination of a plurality of reference frames and a motion vector between the to-be-decoded macroblock and at least one reference frame, (a) encoded data including a predictive error signal for each to-be-decoded macroblock, the first index indicating the combination of a plurality of reference frames, the second index indicating a combination of linear sum weighting factors for reference macroblocks, and information of the motion vector is decoded, (b) a plurality of reference macroblocks are extracted from the plurality of reference frames in accordance with the decoded information of the motion vector and the decoded information of the first index, (c) a predictive macroblock is generated by calculating the linear sum of the plurality of extracted reference frames by using the combination of weighting factors indicated by the decoded information of the second index, and (d) a video signal is decoded by adding the predictive macroblock and the decoded predictive error signal for each of the to-be-decoded macroblocks.

<Effects>

The data encoded in (1) can be decoded, and the same encoding efficiency improving effect as that in (1) can be obtained.

(33) In (32), an index indicating the combination of linear sum weighting factors is received as header data for each frame or each set of a plurality of frames, and the predictive error signal, the index indicating the combination of reference frames, and the motion vector are received and decoded for each macroblock.

<Effects>

The data encoded in (2) can be decoded, and the same encoding efficiency improving effect as that in (2) can be obtained.

(34) In (32) or (33), the received motion vector is a motion vector associated with a specific one of the plurality of reference frames, the received motion vector is scaled in accordance with the inter-frame distance between the to-be-decoded frame and the reference frame, and a motion vector for another or other reference frames is generated by using the scaled motion vector.

<Effects>

The data encoded in (3) can be decoded, and the same encoding efficiency improving effect as that in (3) can be obtained.

(35)　In (34), the motion vector associated with the specific reference frame is a motion vector normalized in accordance with the inter-frame distance between the reference frame and the frame to be

5　encoded.

<Effects>

The data encoded in (4) can be decoded, and the same encoding efficiency improving effect as that in (4) can be obtained.

10　(36)　In (34), the motion vector associated with the specific reference frame is a motion vector for one of the plurality of reference frames which corresponds to the greatest inter-frame distance from the frame to be encoded.

15　<Effects>

The data encoded in (5) can be decoded, and the same encoding efficiency improving effect as that in (5) can be obtained.

(37)　In (32) or (33), the received motion vector

20　is a differential vector between the first motion vector associated with a specific one of the plurality of reference frames and another or other reference frames.　The first motion vector is scaled in accordance with the inter-frame distance between a

25　to-be-encoded frame and the one or a plurality of reference frames.　A motion vector for another or other reference frames is generated by adding the scaled

motion vector and the differential vector for the received one or a plurality of reference frames.

<Effects>

The data encoded in (6) can be decoded, and the same encoding efficiency improving effect as that in (6) can be obtained.

(38) In (37), the received first motion vector is a motion vector normalized in accordance with the inter-frame distance between the reference frame and the frame to be encoded.

<Effects>

The data encoded in (7) can be decoded, and the same encoding efficiency improving effect as that in (7) can be obtained.

(39) In (37), the received first motion vector is a motion vector for one of the plurality of reference frames which corresponds to the greatest inter-frame distance from the frame to be encoded.

<Effects>

The data encoded in (8) can be decoded, and the same encoding efficiency improving effect as that in (8) can be obtained.

(40) In any one of (32) to (39), when information associated with the number of skipped macroblocks is received for each macroblock, and one or more macroblocks are skipped, all motion vector elements required to decode each of the skipped macroblocks are

regarded as 0. By using a predetermined combination of reference frames, reference macroblocks are extracted from the plurality of reference frames. A predictive macroblock is generated from the plurality of reference macroblocks by a linear sum based on an index indicating the combination of the received linear sum weighting factors. The predictive macroblock is used as a decoded picture.

<Effects>

The data encoded in (9) can be decoded, and the same encoding efficiency improving effect as that in (9) can be obtained.

(41) In any one of (32) to (39), when information associated with the number of skipped macroblocks is received for each macroblock, and one or more macroblocks are skipped, reference macroblocks are extracted, for each of the skipped macroblocks, from the plurality of reference frames by using a motion vector for the immediately previously encoded macroblock without being skipped and a predetermined combination of a plurality of reference frames. A predictive macroblock is generated from the plurality of reference frames by a linear sum based on an index indicating the combination of the received linear sum weighting factors. The predictive macroblock is then used as a decoded picture.

<Effects>

The data encoded in (10) can be decoded, and the same encoding efficiency improving effect as that in (10) can be obtained.

(42)　In (40) or (41), the predetermined combination of reference frames includes immediately previously decoded two frames.

<Effects>

The data encoded in (11) can be decoded, and the same encoding efficiency improving effect as that in (11) can be obtained.

(43)　In (40) or (41), an index indicating the predetermined combination of reference frames is received as header data for an encoded frame, and a skipped macroblock is decoded in accordance with the index.

<Effects>

The data encoded in (12) can be decoded, and the same encoding efficiency improving effect as that in (12) can be obtained.

(44)　In any one of (32) to (39), when information associated with the number of skipped macroblocks is received for each macroblock, and one or more macroblocks are skipped, all motion vector elements required to decode each of the skipped macroblocks are regarded as 0.　By using an index indicating a combination of a plurality of reference frames in the

immediately preceding macroblock encoded without being skipped, reference macroblocks are extracted from the plurality of reference frames, and a predictive macroblock is generated from the plurality of reference macroblocks by a linear sum based on the received combination of linear sum weighting factors. The predictive macroblock is used as a decoded picture.

<Effects>

The data encoded in (13) can be decoded, and the same encoding efficiency improving effect as that in (13) can be obtained.

(45) In any one of (32) to (39), when information associated with the number of skipped macroblocks is received for each macroblock, and one or more macroblocks are skipped, reference macroblocks are extracted, for each of the skipped macroblocks, from the plurality of reference frames by using a motion vector for the immediately previously encoded macroblock without being skipped and an index indicating a combination of a plurality of reference frames in the immediately preceding macroblock encoded without being skipped. A predictive macroblock is generated from the plurality of reference frames by a linear sum based on an index indicating the combination of the received linear sum weighting factors. The predictive macroblock is then used as a decoded picture.

<Effects>

The data encoded in (14) can be decoded, and the same encoding efficiency improving effect as that in (14) can be obtained.

5   (46)   In any one of (32) to (39), the received motion vector is encoded as a differential vector with respect to a motion vector predicted from one or a plurality of adjacent macroblocks within a frame. A predictive motion vector is generated from a decoded

10   motion vector for the plurality of adjacent macroblocks.   The predictive motion vector is added to the received motion vector to decode the motion vector for the corresponding macroblock.

<Effects>

15   The data encoded in (15) can be decoded, and the same encoding efficiency improving effect as that in (15) can be obtained.

(47)   In any one of (32) to (39), the following is the 47th characteristic feature.   The received motion

20   vector is encoded as a differential motion vector with respect to a motion vector predicted from a motion vector in a macroblock at the same position in the immediately preceding frame.   By adding the received motion vector and the motion vector predicted from the

25   decoded motion vector in the macroblock at the same position as that in the immediately previously decoded frame, the motion vector for the corresponding

macroblock is decoded.

<Effects>

The data encoded in (16) can be decoded, and the same encoding efficiency improving effect as that in (16) can be obtained.

(48) In any one of (32) to (39), the received motion vector is encoded as a differential motion vector with respect to a motion vector predicted from a motion vector for one or a plurality of adjacent macroblocks in a frame and a motion vector for a macroblock at the same position in the immediately preceding frame. A predictive motion vector is generated from a decoded motion vector for the plurality of adjacent macroblocks and a decoded motion vector for a macroblock at the same position in the immediately previously decoded frame. By adding the predictive motion vector and the received motion vector, the motion vector for the corresponding macroblock is decoded.

<Effects>

The data encoded in (17) can be decoded, and the same encoding efficiency improving effect as that in (17) can be obtained.

(49) In any one of (46) to (48), when information associated with the number of skipped macroblocks is received for each macroblock, and one or more macroblocks are skipped, reference macroblocks are

extracted, for each of the skipped macroblocks, from the plurality of reference frames by using the predictive motion vector as a motion vector for the skipped macroblock and a predetermined combination of a

5 plurality of reference frames. A predictive macroblock is generated from the plurality of reference frames by a linear sum based on an index indicating the combination of the received linear sum weighting factors. The predictive macroblock is then used as a

10 decoded picture.

<Effects>

The data encoded in (18) can be decoded, and the same encoding efficiency improving effect as that in (18) can be obtained.

15 (50) In any one of (46) to (48), when information associated with the number of skipped macroblocks is received for each macroblock, and one or more macroblocks are skipped, reference macroblocks are extracted, for each of the skipped macroblocks, from

20 the plurality of reference frames by using a motion vector obtained by adding a motion vector for the immediately preceding macroblock encoded without being skipped to the predictive motion vector and a predetermined combination of a plurality of reference

25 frames. A predictive macroblock is generated from the plurality of reference frames by a linear sum based on an index indicating the combination of the received

linear sum weighting factors. The predictive macroblock is then used as a decoded picture.

<Effects>

The data encoded in (19) can be decoded, and the same encoding efficiency improving effect as that in (19) can be obtained.

(51) In (49) or (50), the predetermined combination of reference frames includes two immediately previously decoded frames.

<Effects>

The data encoded in (20) can be decoded, and the same encoding efficiency improving effect as that in (20) can be obtained.

(52) In (49) or (50), an index indicating the predetermined combination of reference frames is received as header data for an encoded frame, and a skipped macroblock is decoded in accordance with the received index.

<Effects>

The data encoded in (21) can be decoded, and the same encoding efficiency improving effect as that in (21) can be obtained.

(53) In any one of (46) to (48), when information associated with the number of skipped macroblocks is received for each macroblock, and one or more macroblocks are skipped, reference macroblocks are extracted, for each of the skipped macroblocks, from

the plurality of reference frames by using the
predictive motion vector as a motion vector for the
skipped macroblock and an index indicating a
combination of a plurality of reference frames in the
immediately preceding macroblock encoded without being
skipped. A predictive macroblock is generated from the
plurality of reference frames by a linear sum based on
an index indicating the combination of the received
linear sum weighting factors. The predictive
macroblock is then used as a decoded picture.
<Effects>

The data encoded in (22) can be decoded, and the
same encoding efficiency improving effect as that in
(22) can be obtained.

(54) In any one of (46) to (48), when information
associated with the number of skipped macroblocks is
received for each macroblock, and one or more
macroblocks are skipped, reference macroblocks are
extracted, for each of the skipped macroblocks, from
the plurality of reference frames by generating a
motion vector by adding a differential motion vector
for the immediately preceding macroblock encoded
without being skipped to the predictive motion vector
and using an index indicating a combination of a
plurality of reference frames in the immediately
preceding macroblock encoded without being skipped. A
predictive macroblock is generated from the plurality

of reference frames by a linear sum based on an index
indicating the combination of the received linear sum
weighting factors. The predictive macroblock is then
used as a decoded picture.

5   <Effects>

The data encoded in (23) can be decoded, and the
same encoding efficiency improving effect as that in
(23) can be obtained.

(55)   In a video decoding method of performing
10 motion compensation predictive inter-frame decoding of
a to-be-decoded macroblock of a video picture by using
a predetermined combination of a plurality of reference
frames and a motion vector between the to-be-decoded
macroblock and at least one reference frame, (a)
15 encoded data including a predictive error signal for
each to-be-decoded macroblock, the first index
indicating the combination of a plurality of reference
frames, the second index indicating the frame number of
an encoded frame, and information of the motion vector
20 is decoded, (b) a plurality of reference macroblocks
are extracted from the plurality of reference frames in
accordance with the decoded information of the motion
vector and the decoded information of the first index,
(c) the inter-frame distances between the plurality of
25 reference frames and the encoded frame are calculated
in accordance with the decoded information of the
second index, (d) a predictive macroblock is generated

by calculating the linear sum of the plurality of extracted reference macroblocks using weighting factors determined in accordance with the calculated inter-frame distances, and (e) a video signal is decoded by adding the predictive macroblock and the decoded predictive error signal.

<Effects>

The data encoded in (24) can be decoded, and the same encoding efficiency improving effect as that in (24) can be obtained.

(56)   In a video decoding method of performing motion compensation predictive inter-frame decoding of a to-be-decoded macroblock of a video picture by using at least one past reference frame and a motion vector between the to-be-decoded macroblock and at least one reference frame, (a) encoded data including a predictive error signal for each to-be-decoded macroblock and information of one of the encoded first motion vector or a flag indicating the use of the second motion vector for a macroblock at the same intra-frame position as in an immediately previously encoded frame are received and decoded, (b) a predictive macroblock is generated by using the decoded first motion vector for a to-be-decoded macroblock for which the information of the first motion vector is received and using the second motion vector for a to-be-decoded macroblock for which the flag is

received, and (c) a video signal is decoded by adding
the predictive macroblock and the predictive error
signal.

<Effects>

5   The data encoded in (29) can be decoded, and the
same encoding efficiency improving effect as that in
(29) can be obtained.

       (57)   In a video decoding method of performing
motion compensation predictive inter-frame decoding of
10   a to-be-decoded macroblock of a video picture by using
a motion vector between the to-be-decoded macroblock
and at least one reference frame, (a) encoded data
including information of a predictive error signal for
each to-be-decoded macroblock, prediction mode
15   information indicating one of the first prediction mode
of using at least one to-be-encoded past frame as the
reference frame, the second mode of using a
to-be-encoded future frame as the reference frame, the
third prediction mode of using the linear sum of
20   to-be-encoded past and future frames as the reference
frame, and the fourth mode of using the linear sum of
the plurality of to-be-encoded past frames as the
reference frame, and the information of the motion
vector is received and decoded, (b) a predictive
25   macroblock signal is generated by using the prediction
mode information and the information of the motion
vector, and (c) a video signal is decoded by adding the

predictive macroblock signal and the decoded predictive error signal.

<Effects>

The data encoded in (30) can be decoded, and the same encoding efficiency improving effect as that in (30) can be obtained.

(58) In (57), the prediction based on the linear sum includes linear interpolation and linear extrapolation corresponding to inter-frame distances.

<Effects>

The data encoded in (31) can be decoded, and the same encoding efficiency improving effect as that in (31) can be obtained.

(59) In a video encoding method of performing motion compensation predictive inter-frame encoding of a to-be-encoded macroblock of a video picture by using at least one reference frame selected from a plurality of reference frames and a motion vector between the to-be-encoded macroblock and at least one reference frame, the motion compensation predictive inter-frame encoding is skipped with respect to a to-be-encoded macroblock when the motion vector coincides a predictive vector selected from motion vectors for a plurality of macroblocks adjacent to the to-be-encoded macroblock of the video picture, at least one reference frame selected for the to-be-encoded macroblock coincides with the macroblock from which the predictive

vector is selected, and all to-be-encoded predictive

error signals in the motion compensation predictive

inter-frame encoding are 0, and the number of

macroblocks for which the motion compensation

5   predictive inter-frame encoding is skipped in

performing motion compensation predictive inter-frame

encoding of the next to-be-encoded macroblock is

encoded.

<Effects>

10   As in (22), macroblock skipping is efficiently

caused by using motion vector/reference frame selection

correlation in an inter-frame prediction between

adjacent macroblocks. This makes it possible to reduce

the encoding overhead and improve the encoding

15   efficiency. In addition, when the use of the same

reference frame reference frame as that of an adjacent

macroblock used for a prediction of a motion vector is

set as a skipping condition, macroblock skipping can be

caused more efficiently by using a correlation between

20   adjacent macroblocks based on a combination of a motion

vector and a reference frame.

(60)   In a video encoding method of performing

motion compensation predictive inter-frame encoding of

a to-be-encoded macroblock of a video picture by using

25   at least one first reference frame selected from a

plurality of reference frames and a motion vector

between the to-be-encoded macroblock and the first

reference frame, a predictive error signal obtained by the motion compensation predictive inter-frame encoding, the differential vector between a motion vector used for the motion compensation predictive inter-frame encoding and a predictive vector selected from motion vectors between the second reference frame and a plurality of macroblocks adjacent to the to-be-encoded macroblock, and the differential value between an index indicating the first reference frame and an index indicating the second reference frame are encoded.

<Effects>

As in (15) to (17), motion vector information is efficiency encoded by using the correlation between motion vectors between adjacent macroblocks. In addition, with regard to an index associated with a frame, of a plurality of reference frames, to which each macroblock refers, the differential value between an index indicating a reference frame in an adjacent macroblock from which a predictive vector is selected and an index indicating a reference frame in a to-be-encoded macroblock is encoded. This makes it possible to improve the encoding efficiency of an index indicating a reference frame by using the correlation between adjacent macroblocks based on a combination of a motion vector and a reference frame. This can reduce the encoding overhead and perform high-efficiency video

encoding.

(61) In a video decoding method of performing motion compensation predictive inter-frame decoding of a to-be-decoded macroblock of a video picture by using a motion vector between the to-be-decoded macroblock and at least one reference frame selected from a plurality of reference frames, (a) encoded data including a predictive error signal for each to-be-decoded macroblock which is obtained by motion compensation predictive inter-frame encoding, the number of immediately previously skipped macroblocks and information of an index indicating at least one selected reference frame is received and decoded, (b) one predictive vector is selected from motion vectors for a plurality of macroblocks adjacent to the skipped macroblock, (c) a predictive macroblock is generated in accordance with at least one reference frame for the macroblock from which the predictive vector is selected and the predictive vector, and (d) the predictive macroblock is output as a decoded picture signal of the skipped macroblock.

<Effects>

The data encoded in (59) can be decoded, and the same encoding efficiency improving effect as that in (59) can be obtained.

(62) In a video decoding method of performing motion compensation predictive inter-frame decoding of

a to-be-decoded macroblock of a video picture by using
a motion vector between the to-be-decoded macroblock
and at least the first reference frame selected from a
plurality of reference frames, (a) encoded data
5   including a predictive error signal obtained by motion
compensation predictive inter-frame encoding, the
differential vector between a motion vector used for
the motion compensation predictive inter-frame encoding
and a predictive vector selected from the motion
10   vectors between a plurality of macroblocks adjacent to
the to-be-decoded macroblock and the second reference
frame, and the differential value between the first
index indicating the first reference frame and the
second index indicating the second reference frame are
15   received and decoded, (b) the predictive vector is
selected from the plurality of macroblocks adjacent to
the to-be-decoded macroblock, (c) the motion vector is
reconstructed by adding the selected predictive vector
and the decoded differential vector, (d) the first
20   index is reconstructed by adding the index of the
reference frame for the macroblock from which the
predictive vector is selected and the decoded
differential value, (e) a predictive macroblock is
generated in accordance with the reconstructed motion
25   vector and the reconstructed first index, and (f) a
decoded reconstructed picture signal of the
to-be-decoded macroblock is generated by adding the

generated predictive macroblock and the decoded
predictive error signal.

<Effects>

The data encoded in (60) can be decoded, and the
same encoding efficiency improving effect as that in
(60) can be obtained.

As described above, video encoding and decoding
processing may be implemented as hardware (apparatuses)
or may be implemented by software using a computer.
Part of the processing may be implemented by hardware,
and the other part may be implemented by software.
According to the present invention, therefore, programs
for causing a computer to execute video encoding or
decoding processing described in (1) to (62) can also
be provided.

As has been described above, according to
the present invention, high-picture quality,
high-efficiency video encoding and decoding schemes
with a low overhead for encoded data can be provided,
which can greatly improve prediction efficiency for
fade-in/fade-out pictures and the like, which
conventional video encoding schemes such as MPEG have
difficulty in handling, without much increasing the
computation amount and cost for encoding and decoding.